A First-Order Comparison of Default Databases between MOVES3 and MOVES2014b

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Background

- MOVES2014 and its two minor updates, MOVES2014a and MOVES2014b, were released in July 2014, November 2015, and August 2018, respectively
- A new model, MOVES3, was made available in November 2020 and officially released in January 2021
- A patch to MOVES3 (version MOVES3.0.1) was then released on March 11 2021
- MOVES3 is considered a major update
- VADEQ has continued its tradition of installing and updating MOVES and SMOKE-MOVES models on a Linux system, currently housed in Advanced Research Computing (ARC) Center at Virginia Tech
- How does MOVES3 differ from MOVES2014b?

MOVES on Linux

- VADEQ has been doing MOVES and SMOKE-MOVES modeling on Linux platform since MOVES was in its infancy (the first version, MOVES2009)
- MOVES3 installation on Linux:
  - MariaDB
    - Replace MySQL in previous versions
    - Permission issues
    - Non-persistent, “on-the-fly” MariaDB (ARC system specific for security reason)
  - Java JDK
  - Google GO (locally compiled inside MOVES3)
  - Nonroad (Fortran codes compiled by gfortran, as stated in readme.txt)
  - Default database movesdb20201105 (sql script generated)
  - Revise the following files accordingly:
    - setenv.sh (environment variables and pre-compiled libs/ must be referenced)
    - MOVESConfiguration.txt
    - WorkerConfiguration.txt
    - manyworkers.txt
- MOVES3 installation and testing (for both onroad and nonroad) have completed

MOVES Default Databases

- How does MOVES3 differ from MOVES2014b?
- First Order (basic or fundamental) analysis
- MariaDB versus MySQL
- Default database comparison: movesdb20181022 versus movesdb20201105 (MOVES3.0.1 default database is movesdb20210209)
- Importance of default database: If local or county specific data is not supplied, data in default database is used in MOVES runs
- Databases consist of various tables in MySQL/MariaDB format

MOVES2014b # of tables in movesdb20181022	MOVES3 # of tables in movesdb20201105
222	237

-- Comparing two MOVES versions
-- Understanding important MOVES parameters

Database Tables Examined

Table Name	Parameters	Notes
(a) sourcetypeagedistribution	Age distribution	Age fractions by year, by 13 vehicle types, and by 31 age bins
(b) sourcetypeage	Relative Mileage Accumulation Rate (RelMAR)	RelMAR fraction by 13 vehicle types and by 31 age bins
(c) hpmsvtypeyear	VMT	Yearly VMT (~1998 to 2060) by 5 HPMS vehicle types
(d) sourcetypeyear	VPOP	Yearly VPOP (~1998 to 2060) by 13 vehicle types
(e) roadtypedistribution	VMT road type distribution	VMT road fraction by 13 vehicle types
(f) monthvmtfraction	VMT temporalization	Month VTM fraction by 13 vehicle types
(g) dayvmtfraction	VMT temporalization	Day VMT fraction by 13 vehicles types, by road type, by weekday/weekend
(h) hourvmtfraction	VMT temporalization	Hour VMT fraction by 13 vehicle types, by road type, by weekend/weekend
(i) sourcetypehour	Hoteling	Daily hoteling hour fraction by weekday/weekend for combination long-haul truck only
(j) avgspeeddistribution	Speed distribution	Daily speed distribution by vehicle types, by road type, by speed bin, by weekend/weekend
(k) regioncounty	Fuel region	Fuel region grouped by county and by year
(l) fuelsupply	Fuel supply	Fuel formulation for each fuel region by month and year
(m) fuelformulation	Fuel properties	Fuel properties for each fuel formulation

-- (a), (b), (c), and (d) are used for allocation or distribution of VMT to 13 vehicle types;
-- (e), (f), (g), (h), and (j) are considered dummy in SMOKE-MOVES;
-- Two studies were presented on MDE Thursday morning webinar (presentations are available for download, see last page)

Outline of Talk

- Focus on parameters
  - EPA do not want them changed
  - Are difficult to change
  - Considered important but not in usual input data collection
- (1) Relative Mileage Accumulation Rate
- (2) Speed distribution (and speed profile)
- (3) Fuels (fuel region, supply, and formulation)
- (4) Age distribution fpr base year and future years (in Appendix)

Remaining parameters (on page 5) which were examined but not included in this talk have been presented elsewhere (presentations are available for download, see last page)

MOVES Decoder

SCC Code: AAFFVVRRPP

AA: Mobile Source (22)
FF: MOVES Fuel Types
VV: MOVES VPOP Source Types
RR: MOVES Road Types (excluding ramps)
PP: MOVES Emission Processes

5 HPMS "observation-based" vehicle types

MOVES2014 VMT Types

HPMStypeID	Classifications
10	Motorcycles
25	Light Duty Vehicles
40	Buses
50	Single Unit Trucks
60	Combination Trucks

HPMS 25, adopted in MOVES2014, is an aggregation of the HPMS 20 and HPMS 30 classifications in MOVES2010b

MOVES2014 VPOP Types

ID	Sourcetypename
11	Motorcycle
21	Passenger Car
31	Passenger Truck
32	Light Commercial Truck
41	Intercity Bus
42	Transit Bus
43	School Bus
51	Refuse Truck
52	Single Unit Short-haul Truck
53	Single Unit Long-haul Truck
54	Motor Home
61	Combination Short-haul Truck
62	Combination Long-haul Truck

13 MOVES vehicle types

MOVES2014 Road Types

roadTypeID	roadDesc
1	Off-Network
2	Rural Restricted Access
3	Rural Unrestricted Access
4	Urban Restricted Access
5	Urban Unrestricted Access

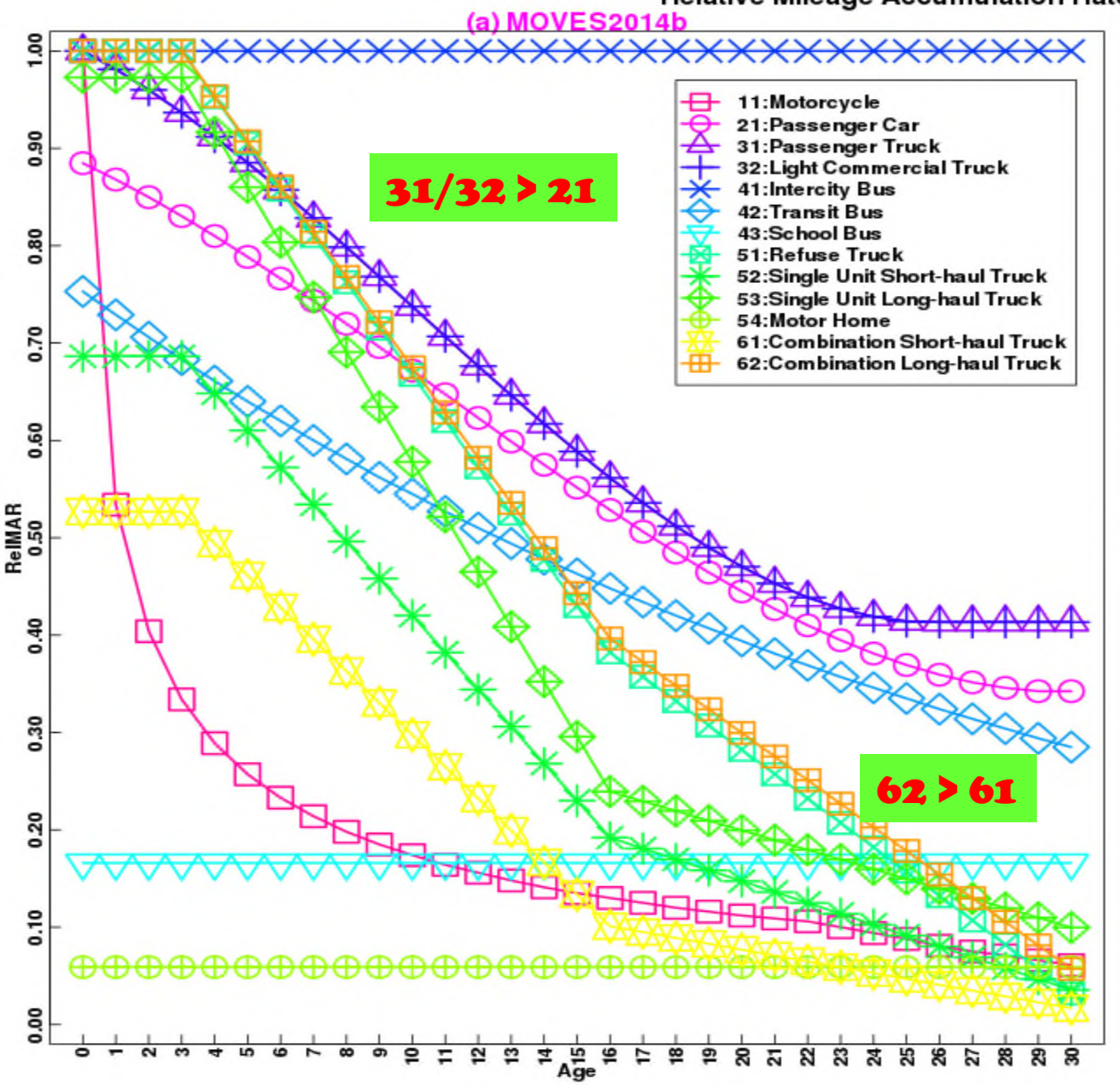
Ramps are not included

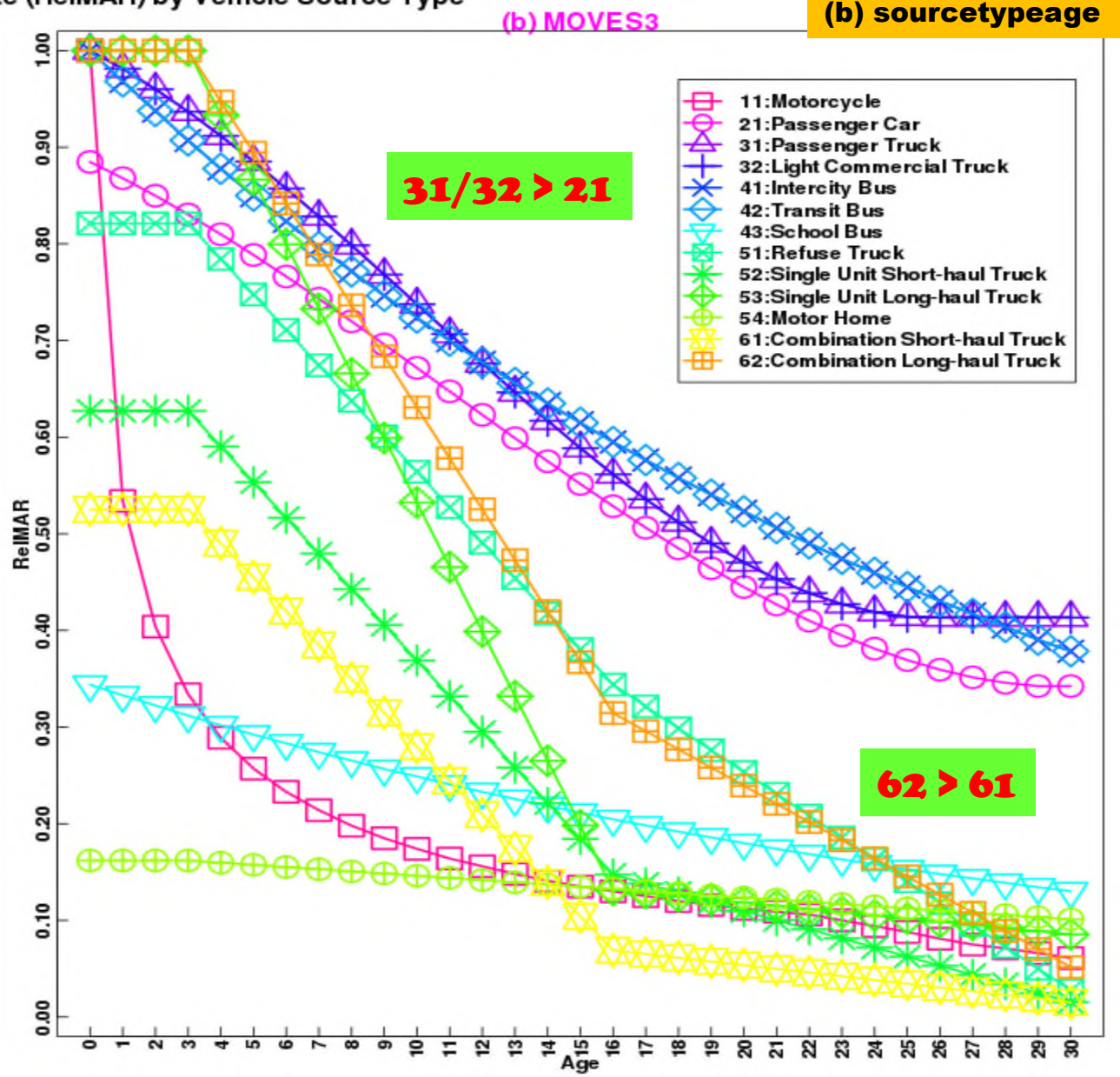
MOVES2014 Fuel Types

fuelTypeID	Fuel Type Description
1	Gasoline
2	Diesel Fuel
3	Compressed Natural Gas (CNG)
4	Liquefied Petroleum Gas (LPG)
5	Ethanol (E85)
9	Electricity

(b) sourcetypeage

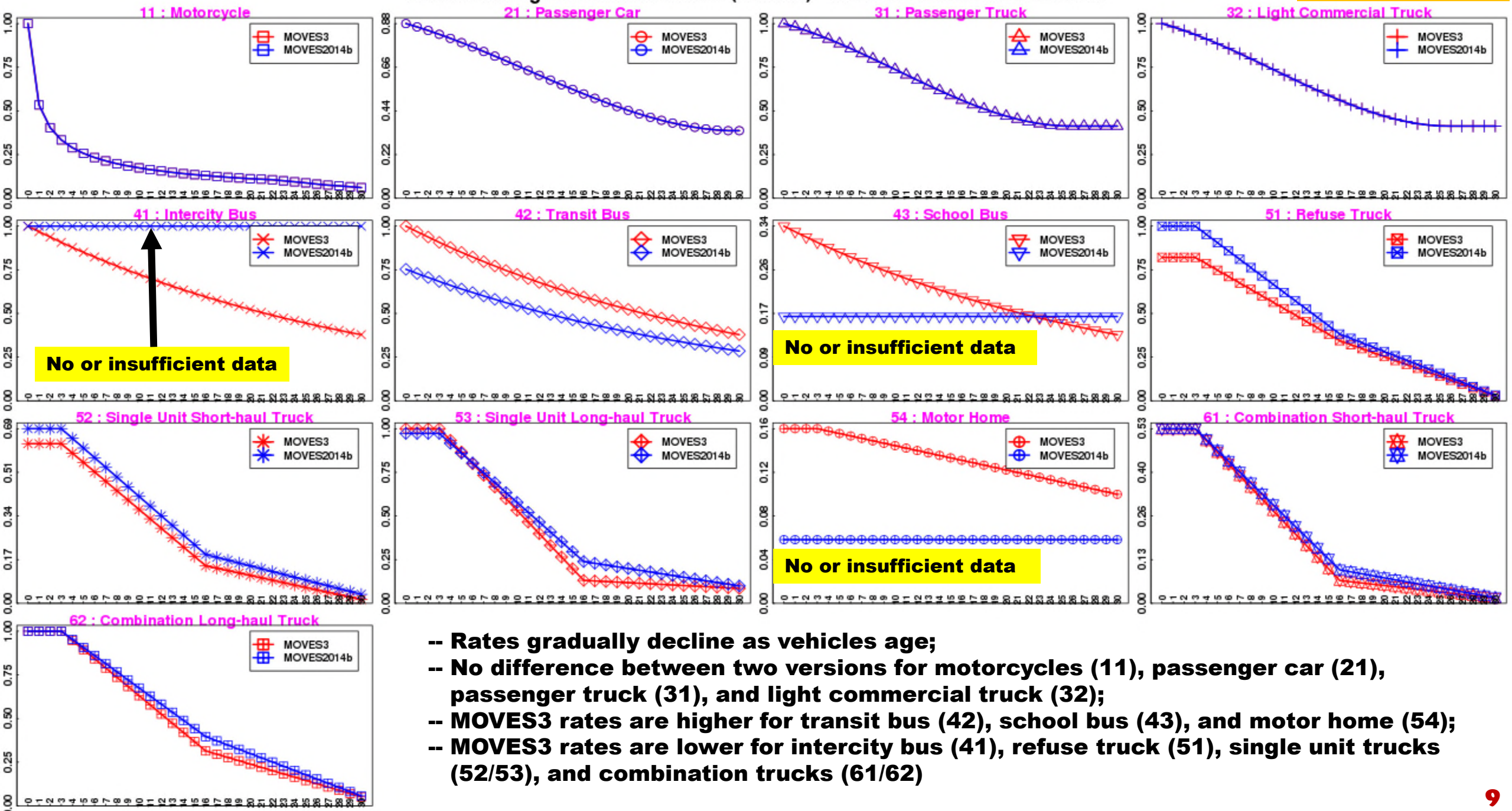
Relative Mileage Accumulation Rate (RelMAR) by Vehicle Source Type





-- Relative Mileage Accumulation Rate (RelMAR) is used to allocate VMT to 13 vehicle types;
-- The data is scaled by a relative point (and thus “relative” mileage accumulation rate);
-- Newer vehicles in general have higher mileage accumulation rates

(b) sourcetypeage



-- Rates gradually decline as vehicles age;
-- No difference between two versions for motorcycles (11), passenger car (21), passenger truck (31), and light commercial truck (32);
-- MOVES3 rates are higher for transit bus (42), school bus (43), and motor home (54);
-- MOVES3 rates are lower for intercity bus (41), refuse truck (51), single unit trucks (52/53), and combination trucks (61/62)

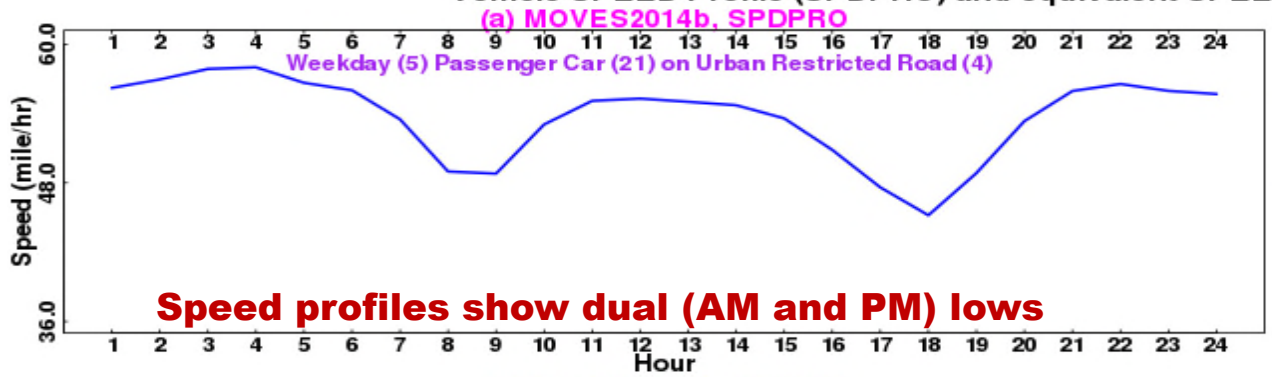
Speed Distribution and Speed Profile

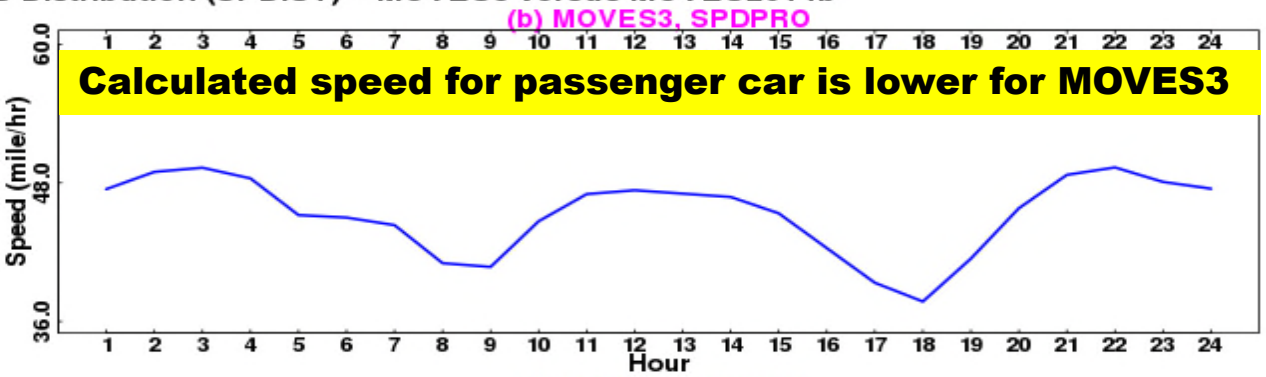
- MOVES uses speed distribution (SPDIST or speed fraction versus speed bin)
- Previously SMOKE could only use speed profile (SPDPRO or actual speed versus hour)
- In SMOKE 4.7 (released in October 2019), for consistency with MOVES, inputs have been revised and speed distribution can be provided as an alternative. The original option of speed profile can still be used as well
- Speed distribution (SPDIST) can be converted to speed profile (SPDPRO) by a conversion equation:

Summarizing multiplication of fraction and average speed over 16 bins for an hour yields a single speed for that hour:

$$\text{Hourly Average Speed} = \sum \text{fraction i} * \text{avg speed for bin_i} \qquad (I = 1..16)$$

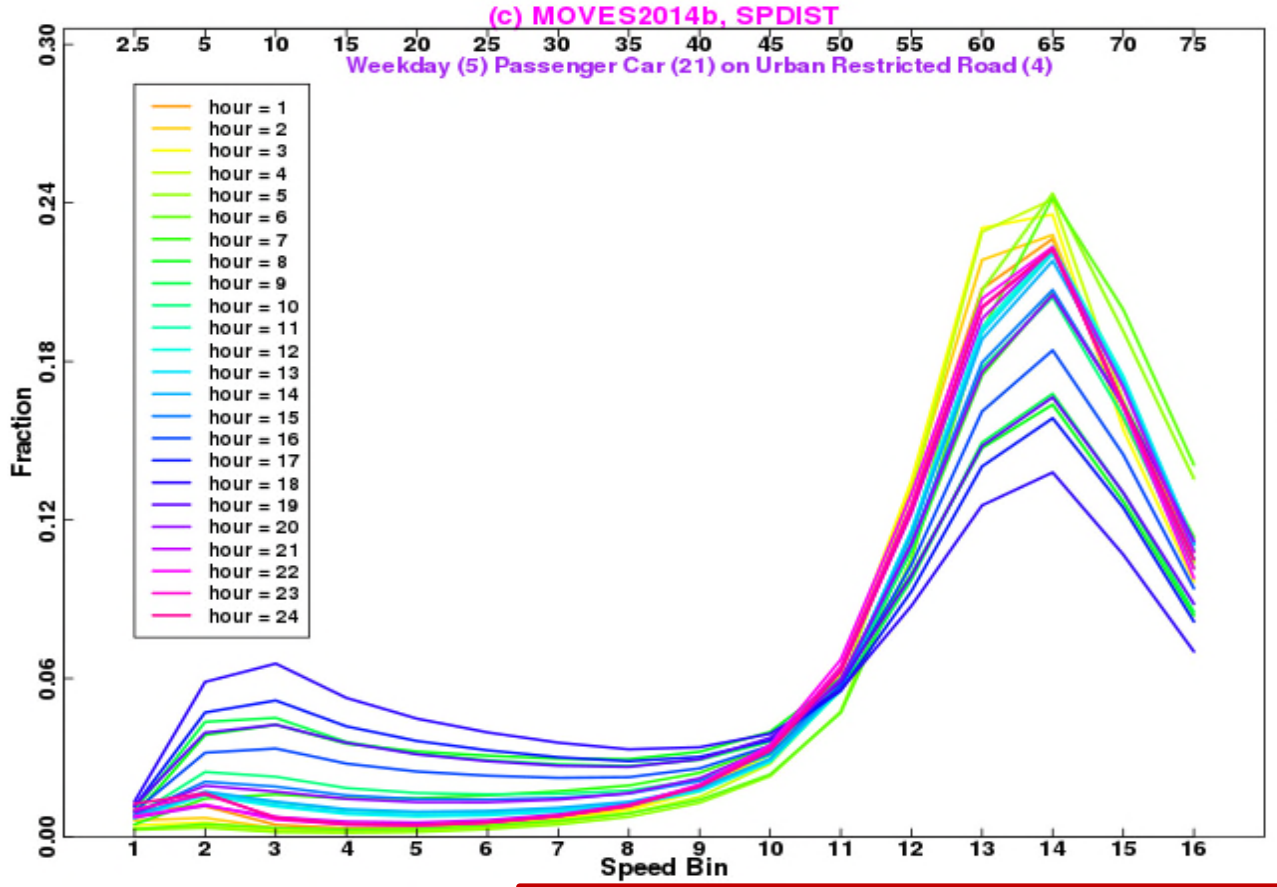
Vehicle SPEED Profile (SPDPRO) and equivalent SPEED Distribution (SPDIST) -- MOVES3 versus MOVES2014b

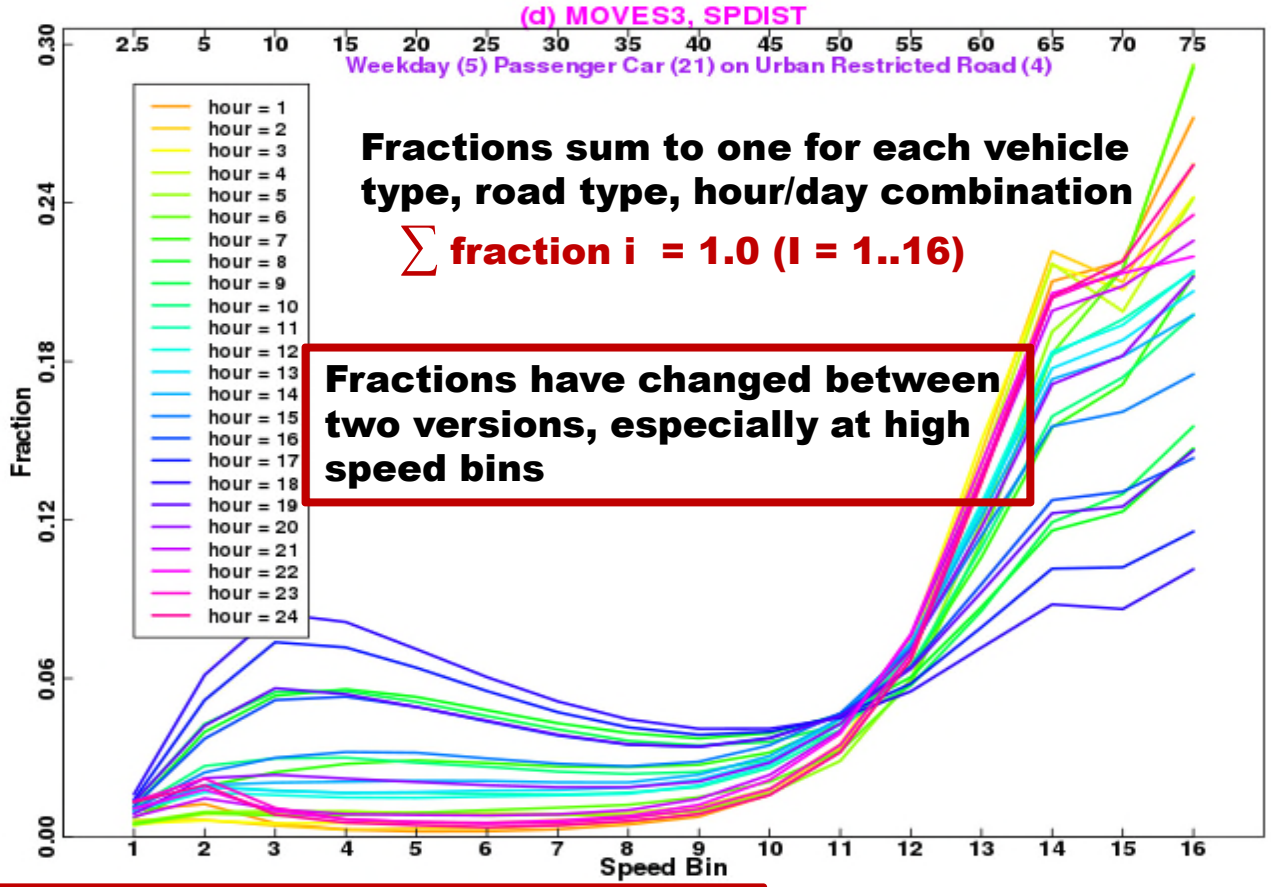




Calculated speed for passenger car is lower for MOVES3

Speed profiles show dual (AM and PM) lows





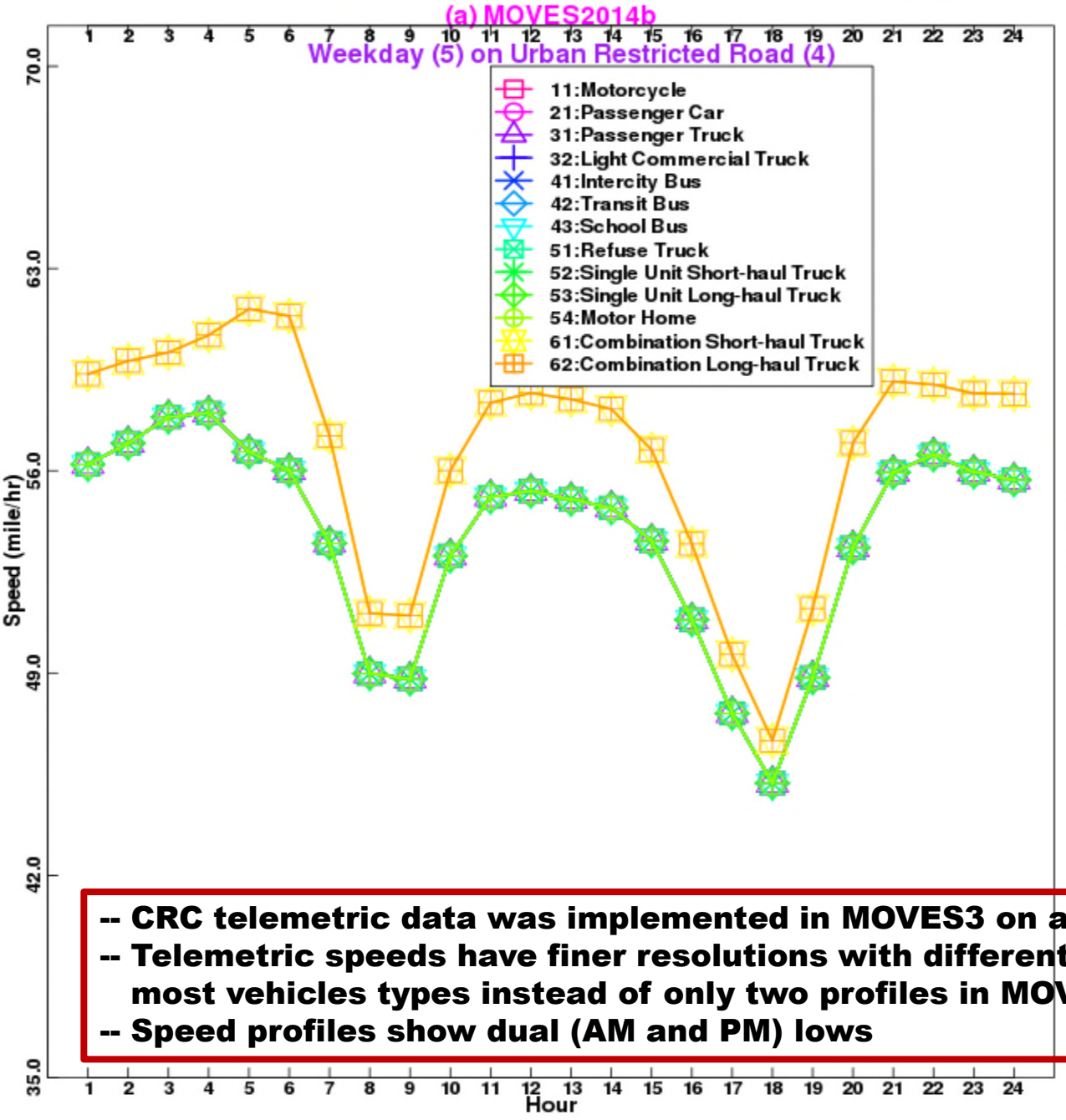
Fractions sum to one for each vehicle type, road type, hour/day combination

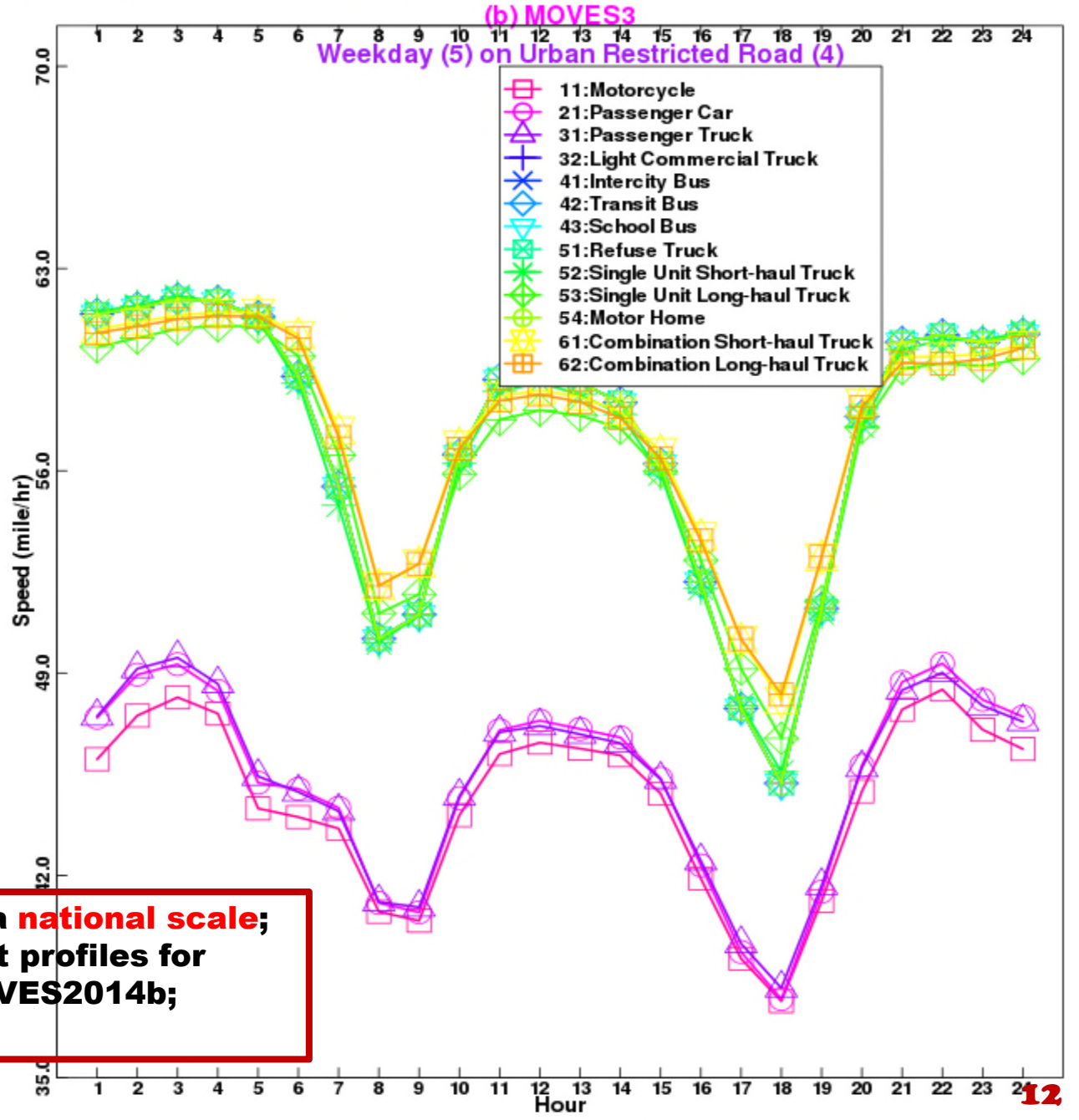
$\sum$ **fraction i = 1.0 (I = 1..16)**

Fractions have changed between two versions, especially at high speed bins

-- Speed distribution vary by vehicle type, road type and weekend/weekend;
-- This figure is for weekday (5) passenger car (21) on urban restricted road (4) only

Vehicle SPEED Profile (SPDPRO) by Vehicle Source Type -- MOVES3 versus MOVES2014b





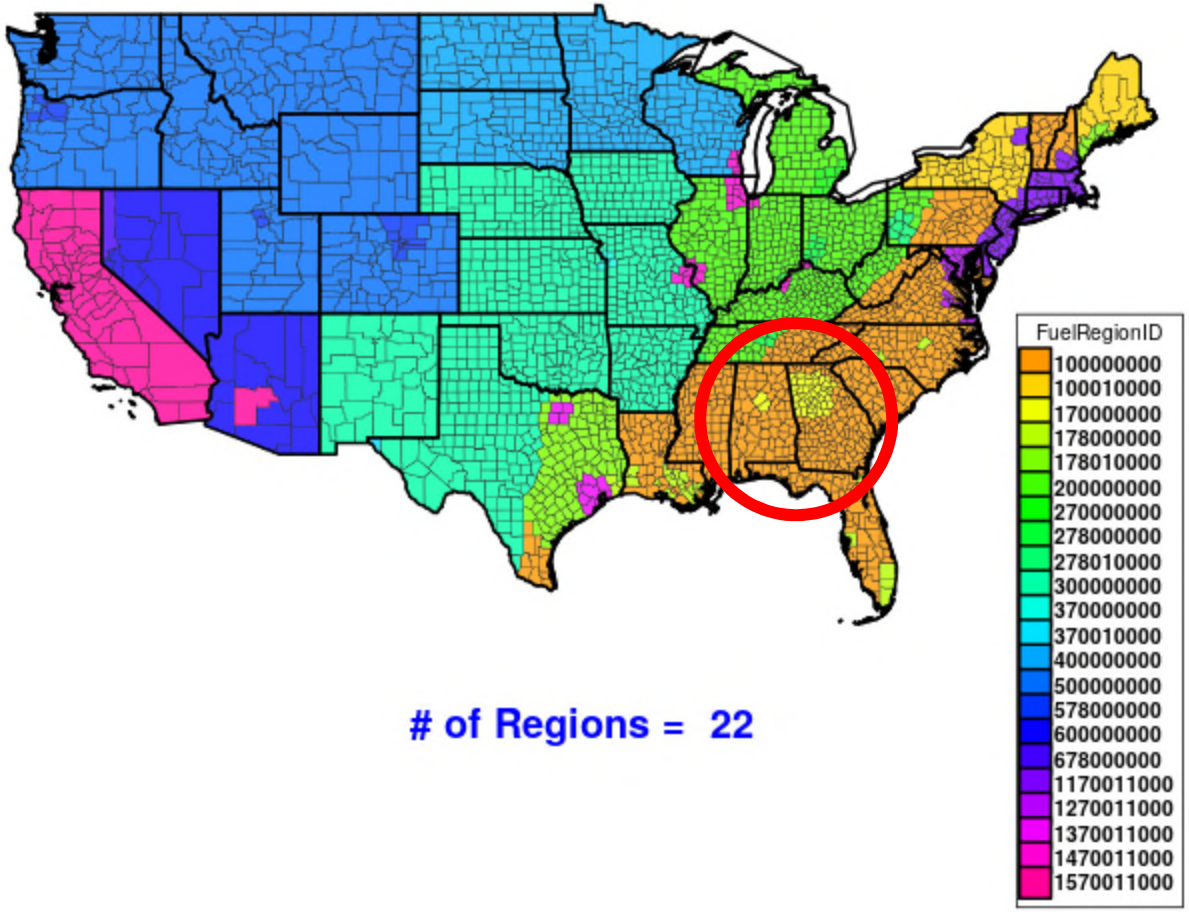
-- CRC telemetric data was implemented in MOVES3 on a national scale;
-- Telemetric speeds have finer resolutions with different profiles for most vehicles types instead of only two profiles in MOVES2014b;
-- Speed profiles show dual (AM and PM) lows

Year 2020 Fuel Regions -- MOVES3 versus MOVES2014b

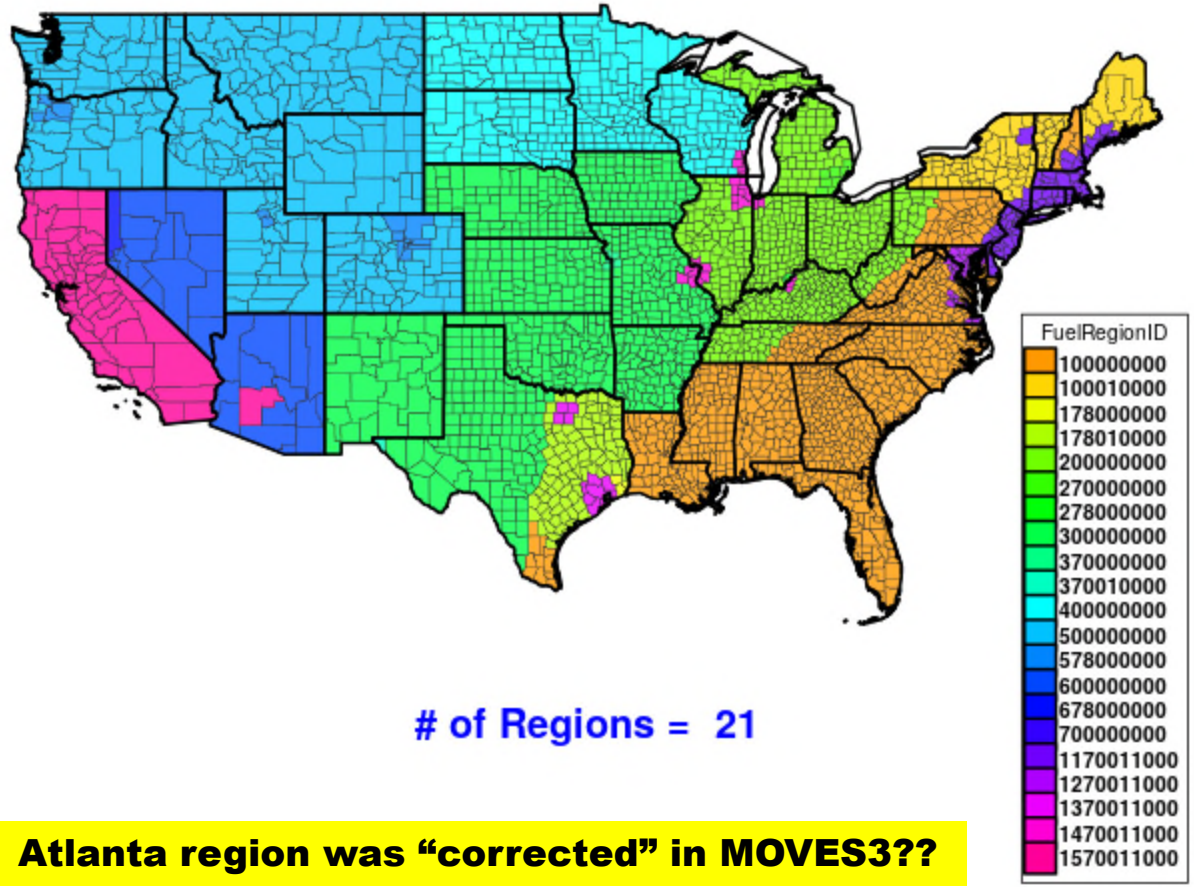
(a) MOVES2014b -- Year 2020 Fuel Regions

(b) MOVES3 -- Year 2020 Fuel Regions

-- Fuel regions vary by county and by calendar year. This figure is for 2020 only;
-- Regioncounty table contains fuel regions for both onroad and nonroad;
-- Fuel regions are the same for both onroad and nonroad;
-- EPA uses refinery data for gasoline formulations for 2014 and later;
-- # of fuel regions has decreased by one in MOVES3



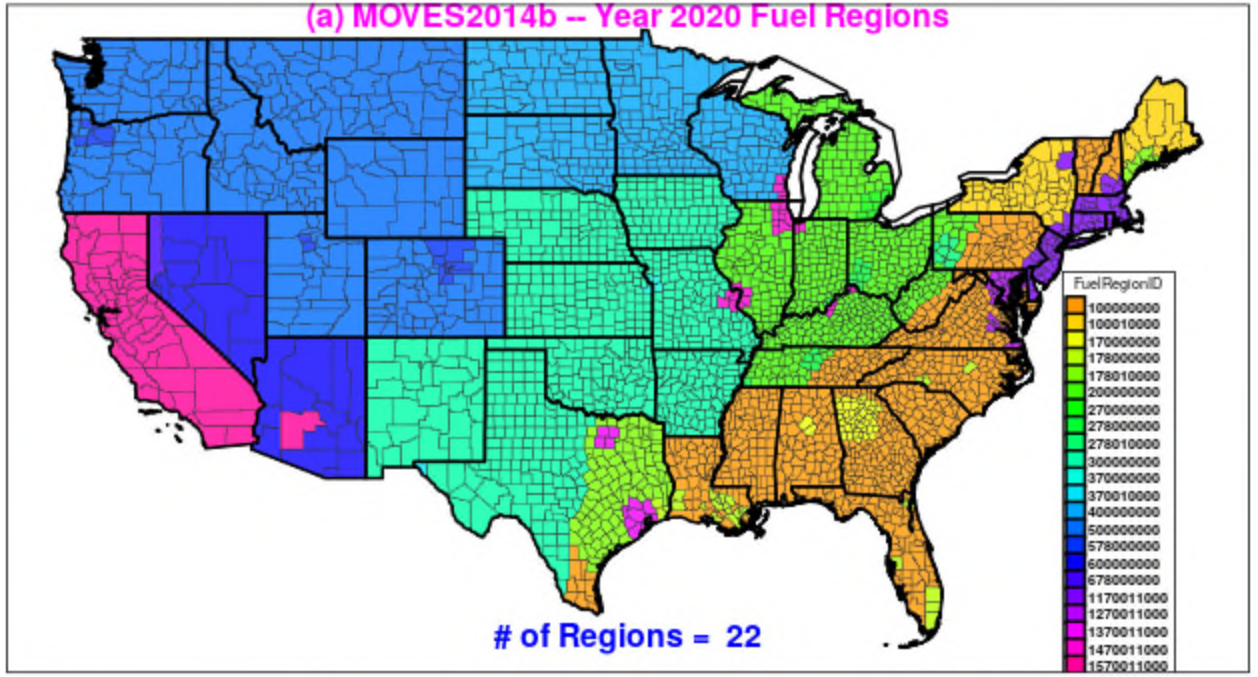
# of Regions = 22

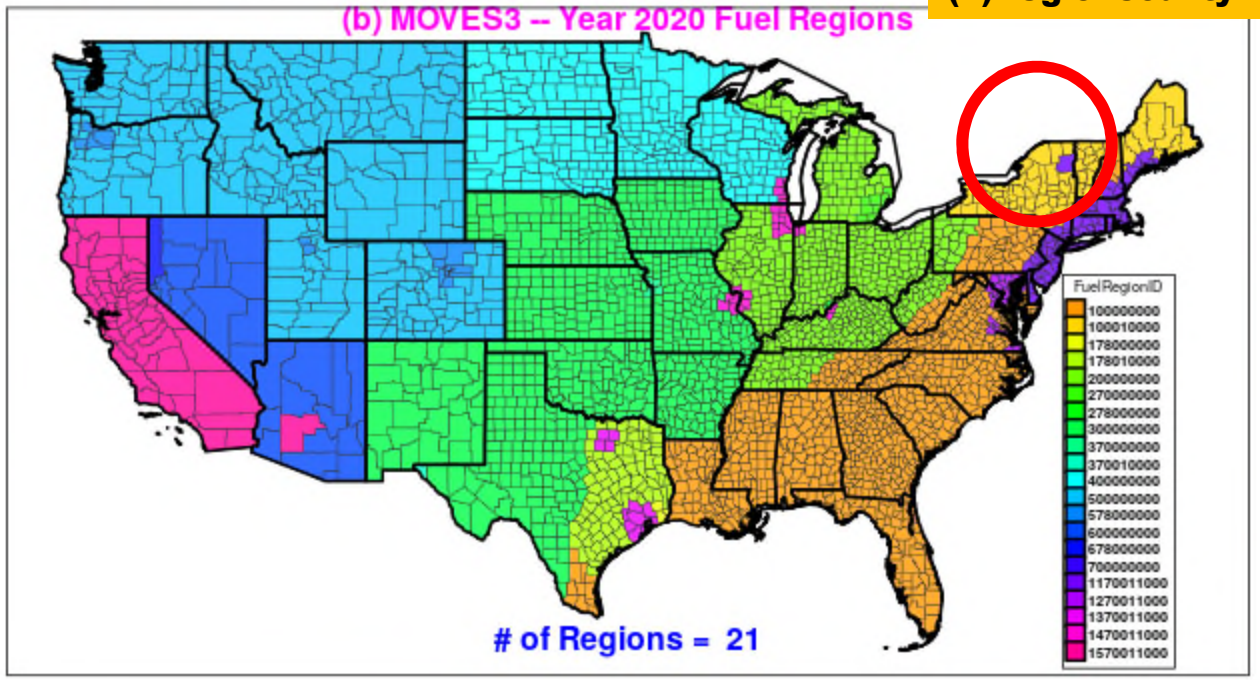


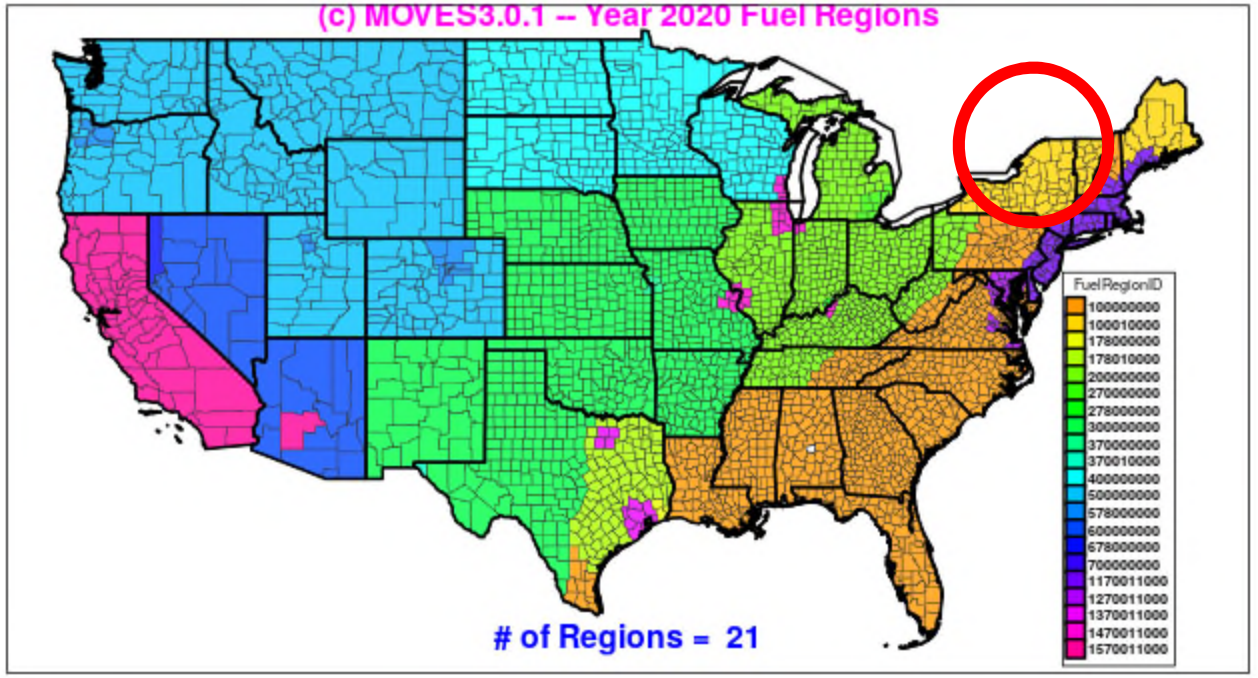
# of Regions = 21

Atlanta region was "corrected" in MOVES3??

Year 2020 Fuel Regions -- MOVES2014b, MOVES3 and MOVES3.0.1



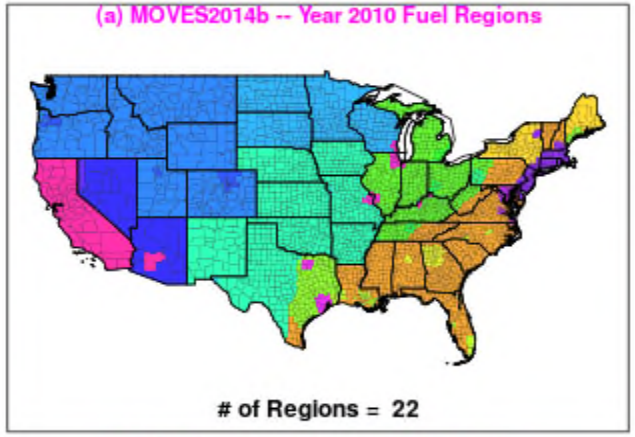


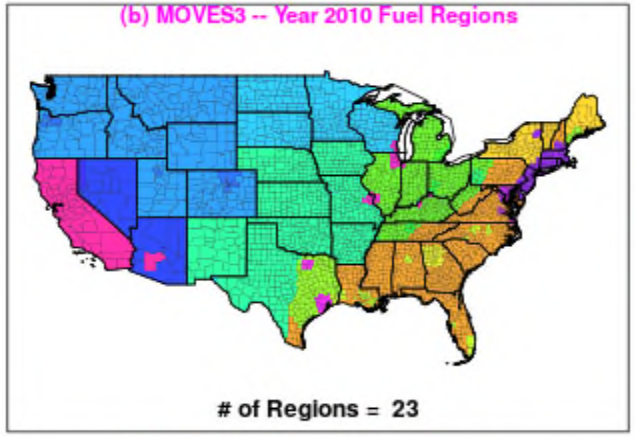


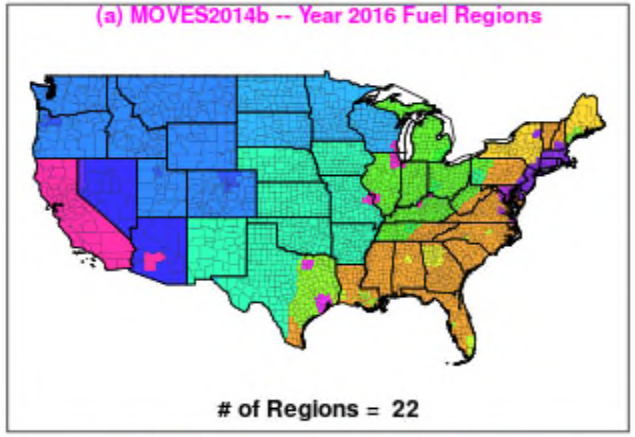
-- Panel (a) and (b) are the same as page 12;
-- Panel (c) is from regionconty table in movesdb20210209 (i.e., default database in MOVES3.0.1);
-- Essex County in NY has been "corrected" in MOVES3.0.1

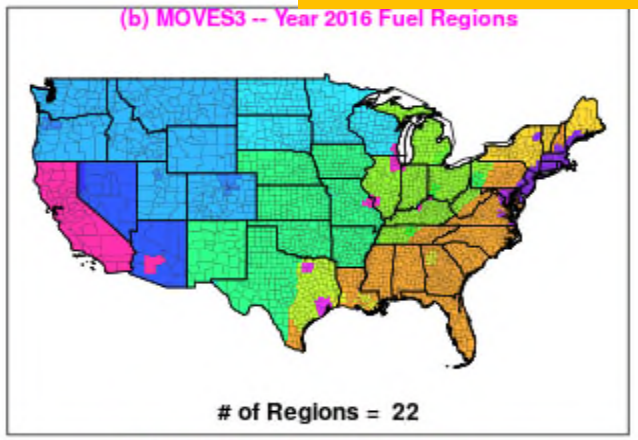
(k) regioncounty

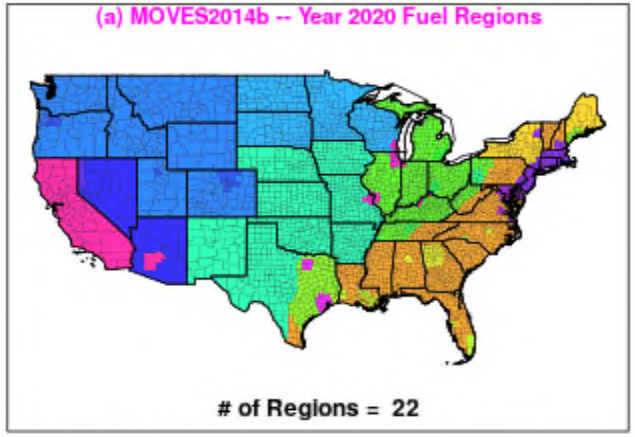
Fuel Regions for Selected Years -- (a) MOVES2014b, (b) MOVES3

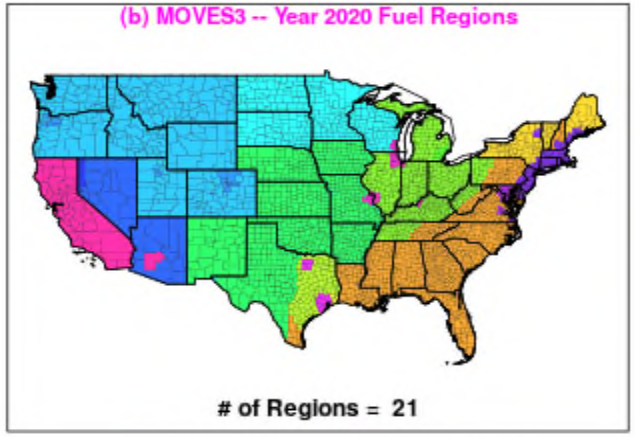


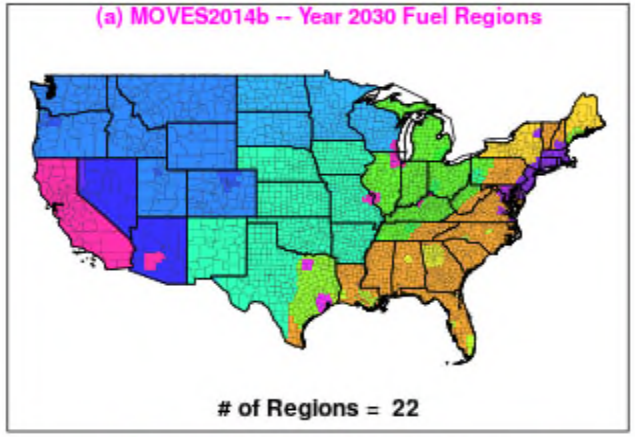


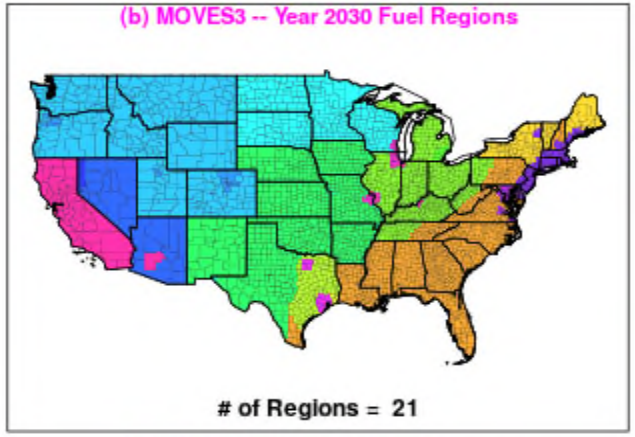


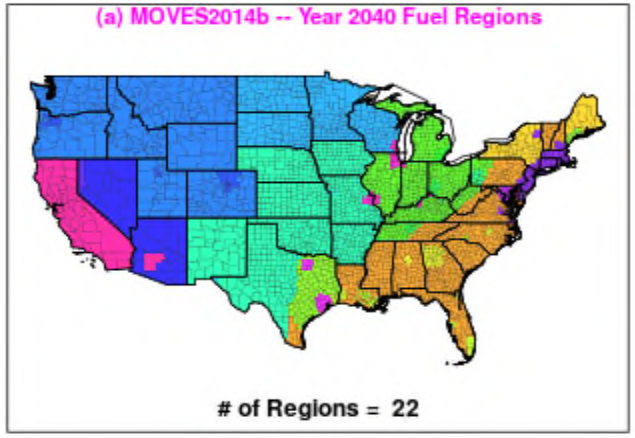


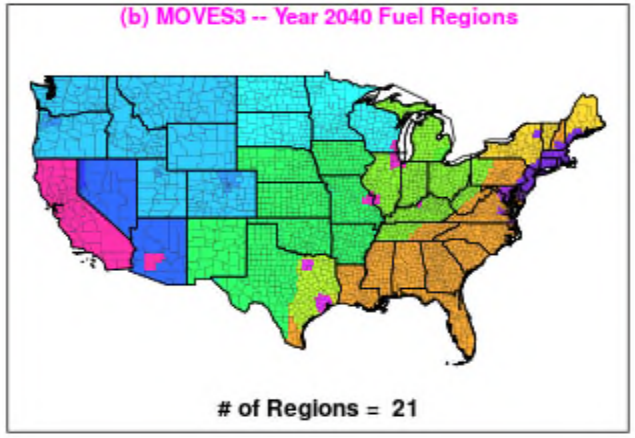


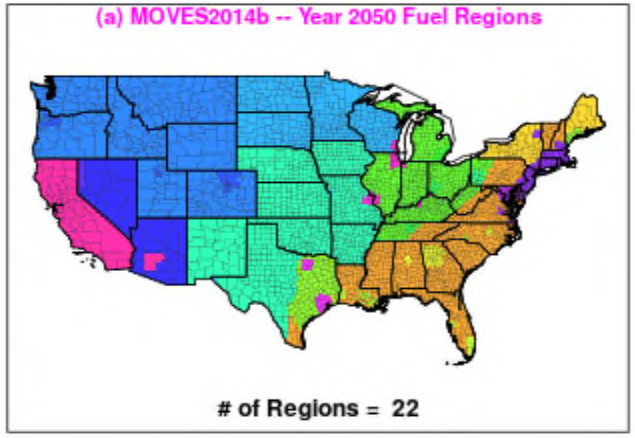


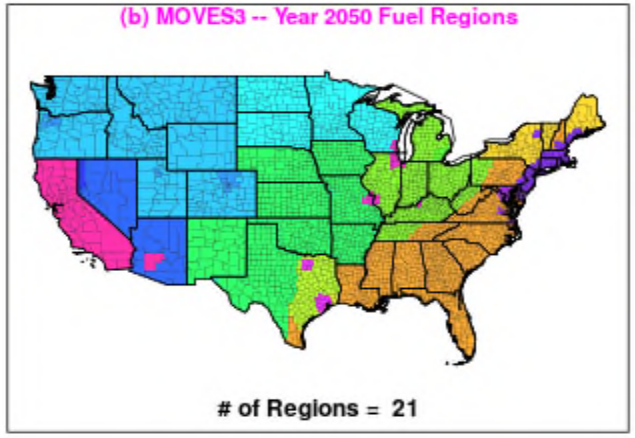






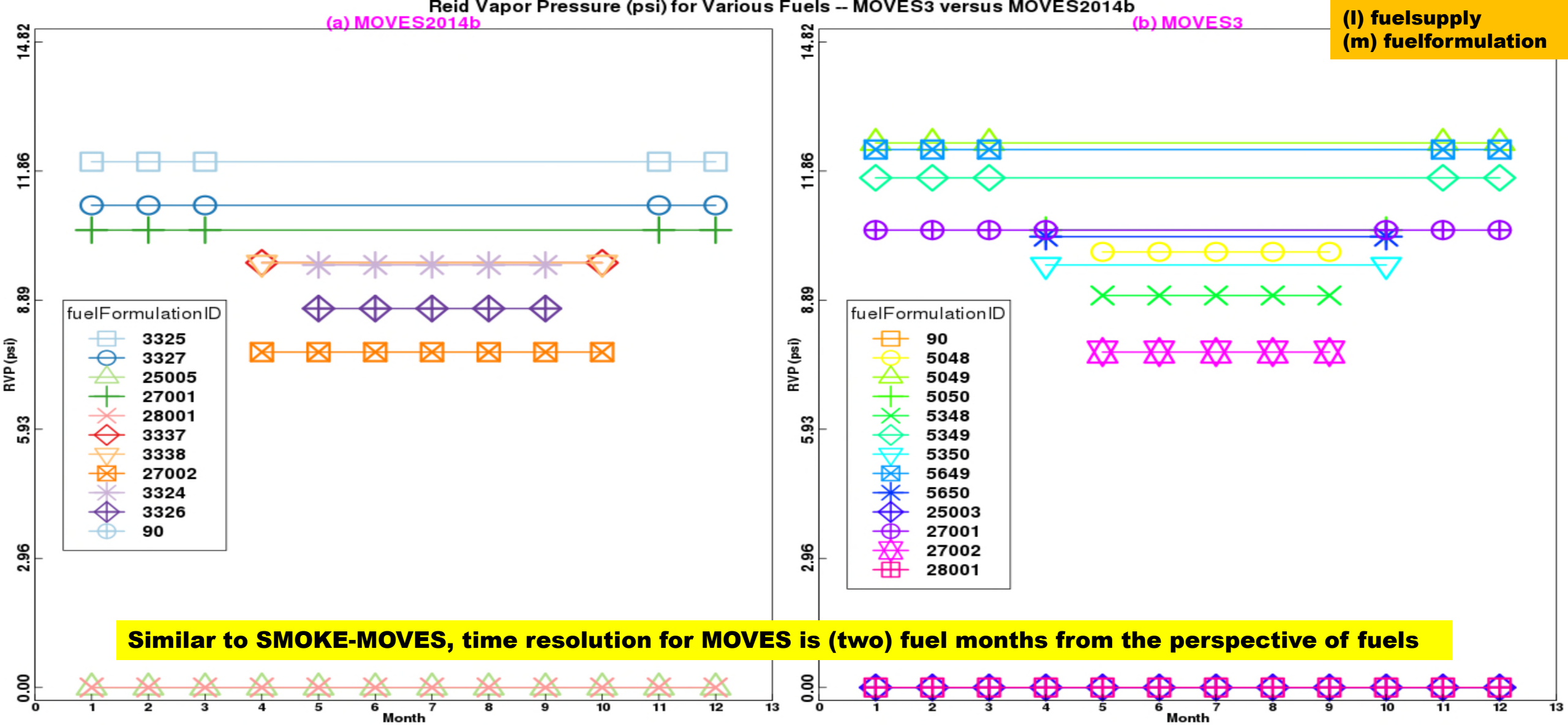






A pair of (a) and (b) can be compared for the same year bw two versions. Six years (2010, 2016, 2020, 2030, 2040, and 2050) are plotted

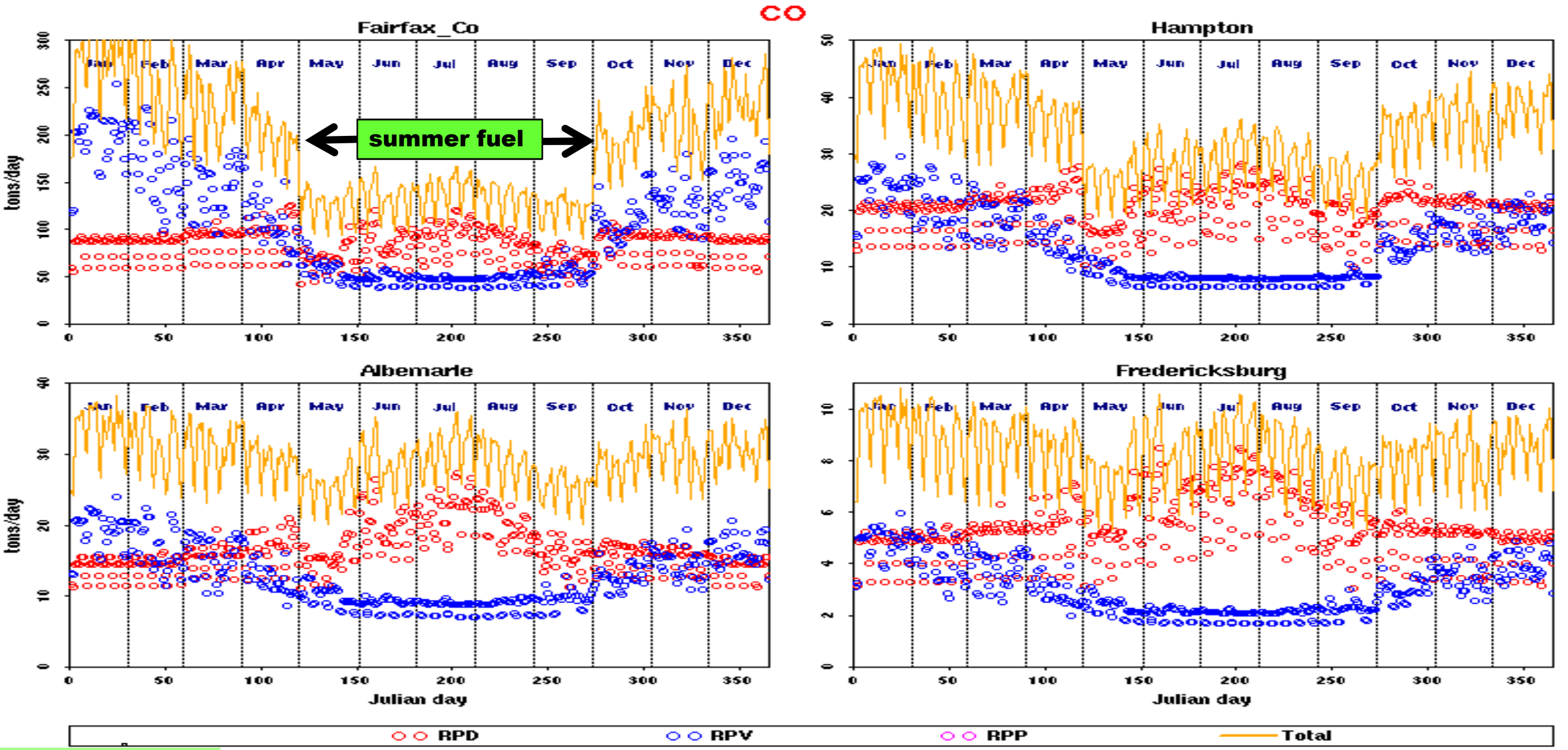
(l) fuelsupply
(m) fuelformulation



Similar to SMOKE-MOVES, time resolution for MOVES is (two) fuel months from the perspective of fuels

-- This figure was made by combining data from fuelsupply and fuelformulation tables. It is for year 2016 and regionID 100000000 only;
-- RVP for non-gasoline fuels (diesel, CNG, electricity) is zero;
-- Gasoline/ethanol fuels generally are grouped into summer fuels and winter fuels (plus or minus shoulder months);
-- RVP for winter fuels > RVP for summer fuels

VA 2011 Daily Temporal Profiles for Vehicular CO Emissions for Four Selected Counties



This plot was made in July 2013

-- Daily profiles by county show diurnal variations. RPP sector (VOCs only) does not contribute to CO;
-- Discontinuity due to two fuel months starts to diminish as county emissions get smaller (Fairfax -> Hampton -> Albemarle -> Fredericksburg).

Summary

- MOVES default database serves as data substitute if no county specific inputs are supplied
- Relative Mileage Accumulation Rate (RelMAR) is used to allocate VMT to 13 vehicle types. The rate declines as vehicles age
- CRC-funded telemetric speed data has been incorporated into MOVES3 (on national scale but not at county level)
- The incorporation of telemetric data has changed speed distribution in MOVES3, especially at higher speed bins. Average speed is now slower for motorcycle (11) and light duty vehicles (21/31), and is higher for all other vehicles (buses and trucks)

Summary (cont.)

- Number of fuel regions has decreased by one in MOVES3. Fuel regions vary by county and by calendar year (extending to future years)
- EPA uses refinery data (not state-supplied data) for fuel-related parameters in NEIs. Close examination of fuel parameters is therefore important
- Gasoline/ethanol fuels generally are grouped into summer fuels and winter fuels. RVP for winter fuels is greater than RVP for summer fuels
- The two fuel-month approach in MOVES is similar to what's in SMOKE-MOVES. As a result, daily VOCs or gas species profiles appear suppressed and show discontinuity
- Future year age distribution profiles converge to a front-end loaded smooth curve, and their average ages become uniform for all vehicle types, indicating possible usage of the age projection tool
- It's not clear how future year age distribution was developed in recent emission modeling by EPA

Web Link for Presentations

https://www.arc.vt.edu/air-quality-modeling

Emission Modeling: ~70 pdf on MOVES, SMOKE-MOVES, and EGUs (from 2011 to present)
Air Quality Modeling: ~35 pdf (from 2016 to present)

Contacts

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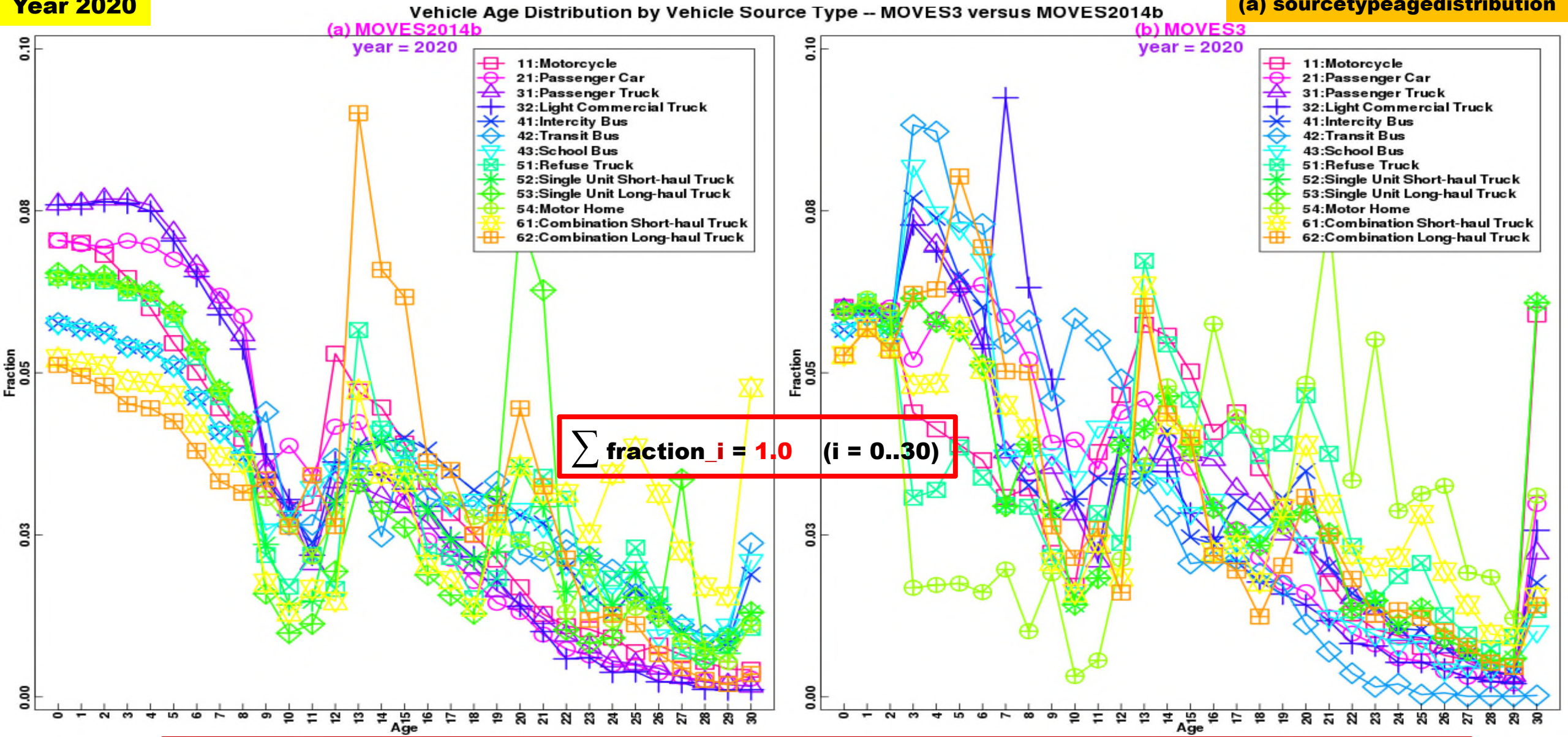
Appendix

Fleet Age Distribution

- Age distribution is one of the most important parameters affecting mobile source emissions
- Traditionally age distribution for onroad sector for base year and future years was assumed to remain the same in emission modeling
- Starting from 2011/2014 NEI, an age projection tool was used to project age distribution into the future
- The age projection tool was in low resolution (VADEQ study)
- The practice introduced extra complexity and uncertainty to an already uncertain future year inventory, affecting emission and air quality modeling
- It's not clear how age distribution for future years has been handled in recent emission modeling by EPA

Year 2020

(a) sourcetypeagedistribution

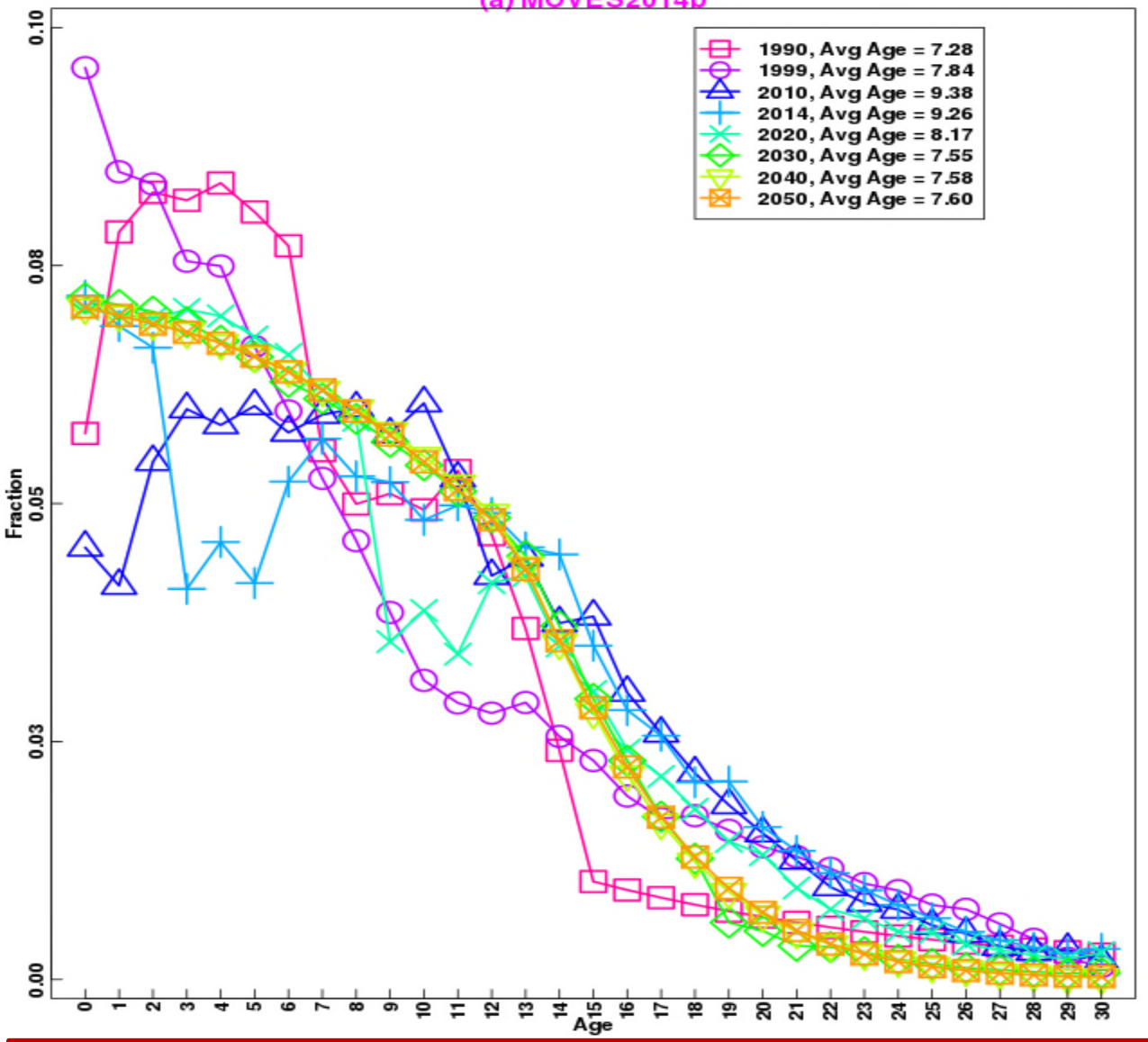


$$\sum \text{fraction_i} = 1.0 \quad (i = 0..30)$$

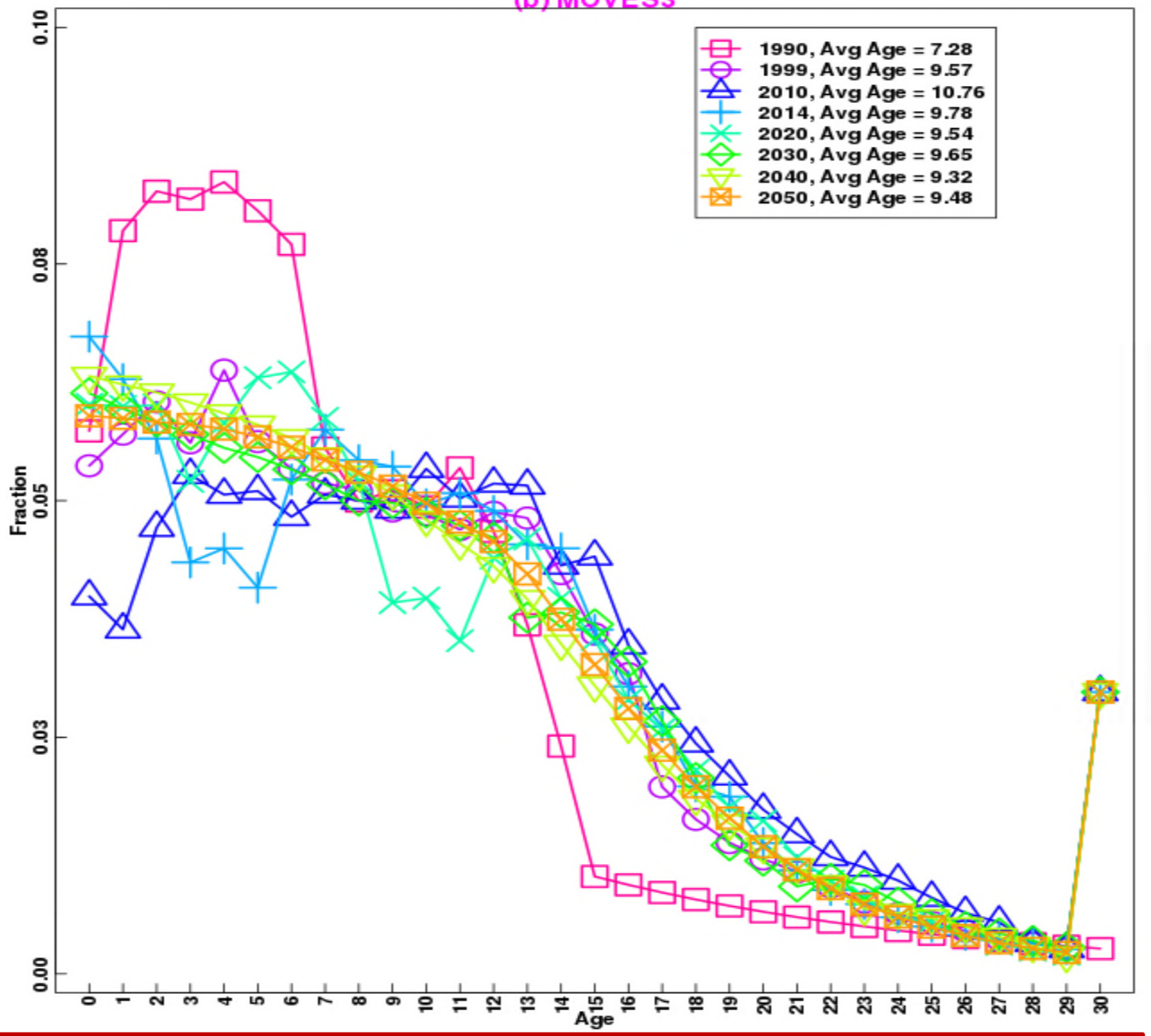
-- Age distribution is one of the most important parameters affecting mobile source emissions;
-- Data varies by year. This figure is for year 2020 only;
-- Only two years of actual data (1990 and 2014) were used to develop default age distribution;
-- Data for all other years were based on projected sales and scrappage (per MOVES3 documentation)

Selected Future Year Age Distributions – Passenger Car (21)

(a) MOVES2014b

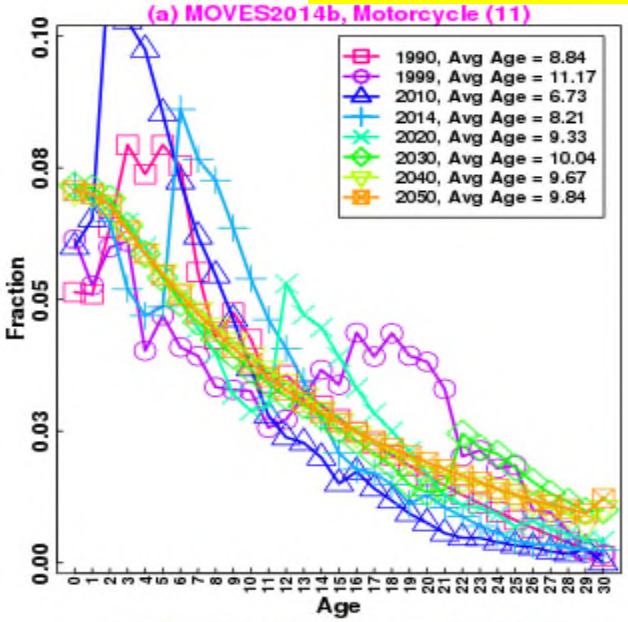


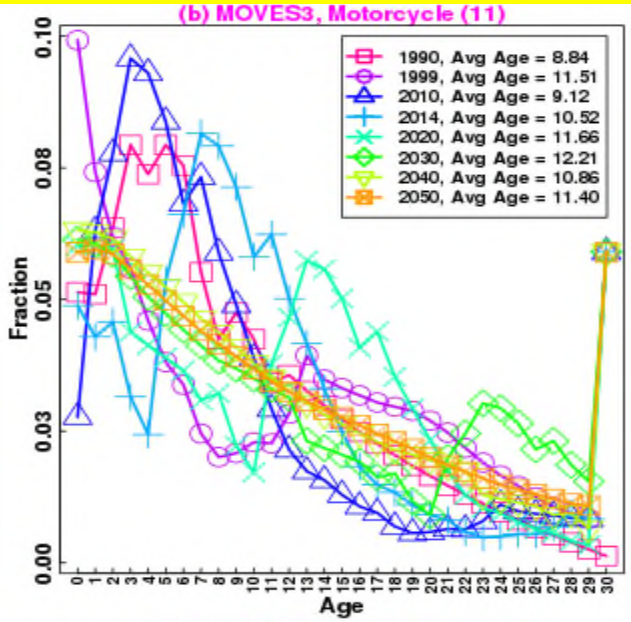
(b) MOVES3

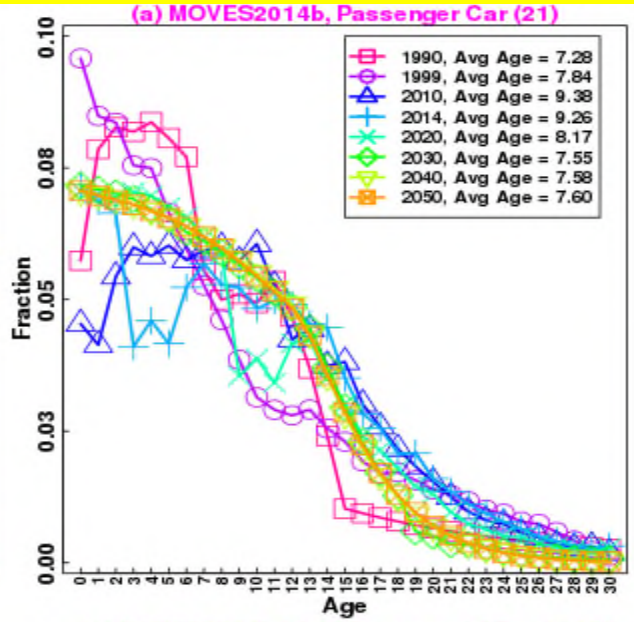


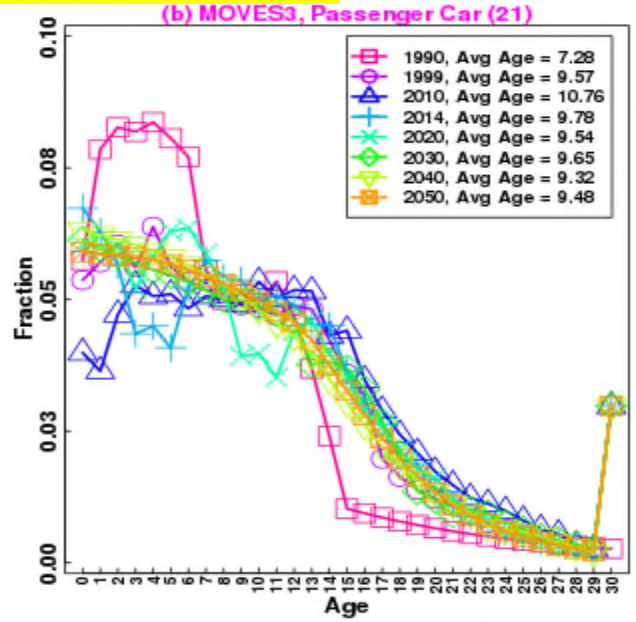
-- Age distribution for passenger car (21) in 8 selected years (1990, 1999, 2010, 2014, 2020, 2030, 2040, 2050) are plotted;
-- MOVES3 has incorporated VIN-decoded data (of 2014), as evidenced by sharp increase in fraction at age 30;
-- Profiles are similar in shape between two versions, and they converge to a smooth curve, both of which indicating possible usage of the age projection tool

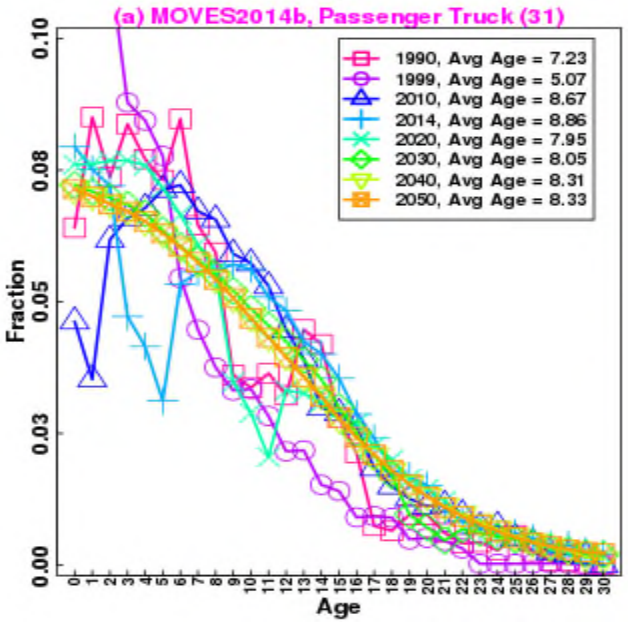
Selected Future Year Age Distributions -- Motorcycle and Light Duty Vehicles (11, 21, 31, 32)

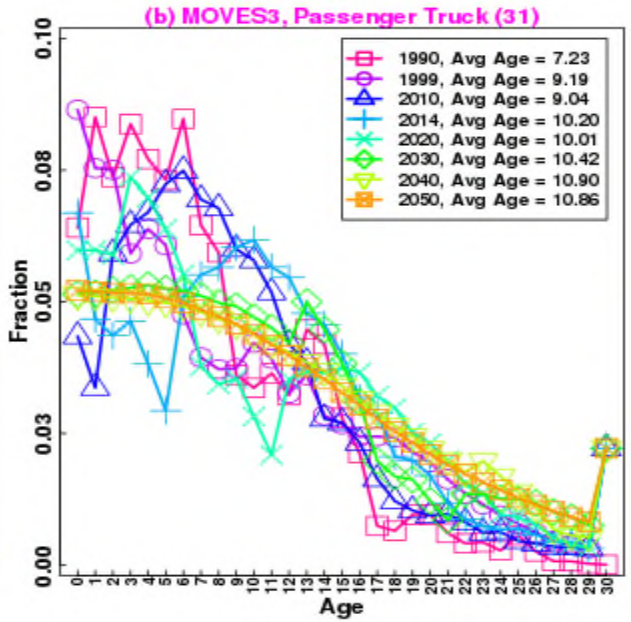


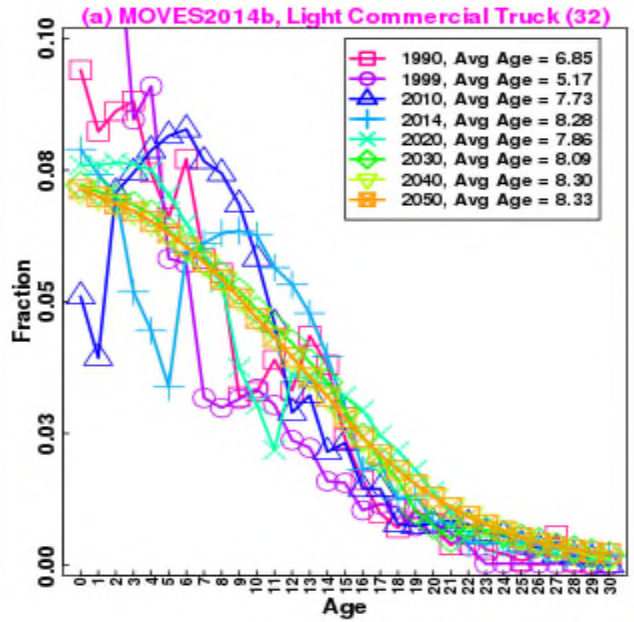


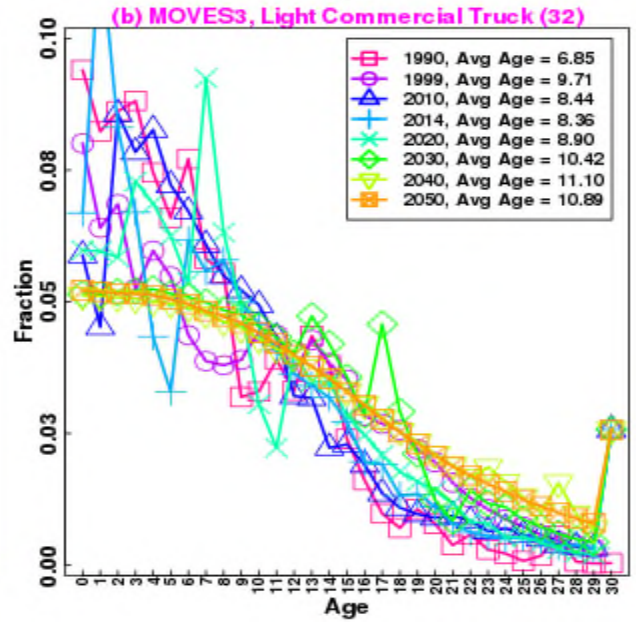






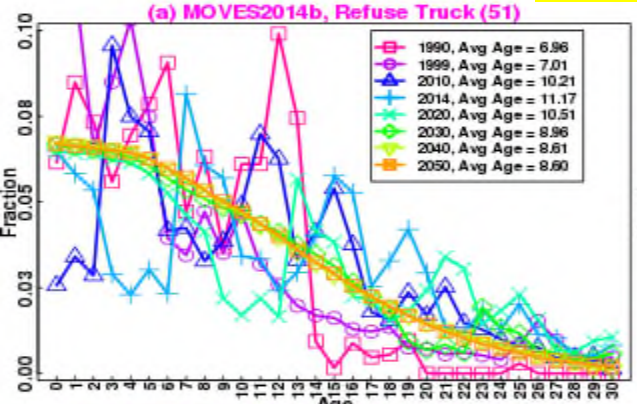


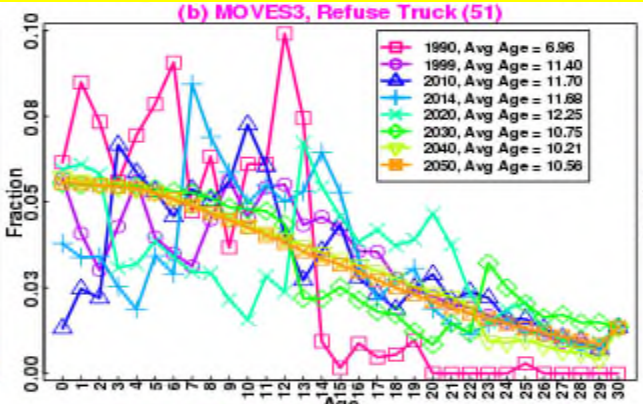


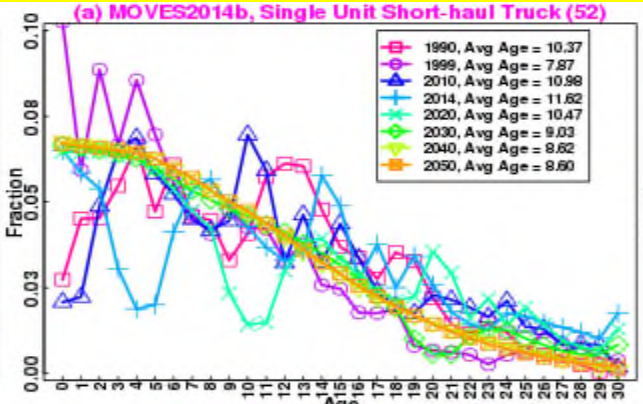


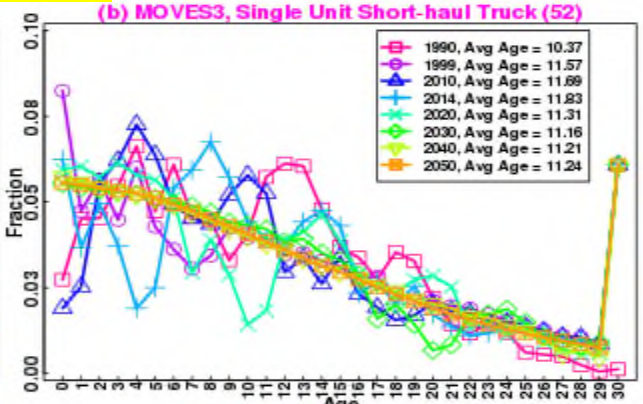
-- A pair of (a) and (b) can be compared between two versions for the same vehicle types;
-- Eight selected years (1990, 1999, 2010, 2014, 2020, 2030, 2040, and 2050) are plotted;
-- Future year profiles converge to a smooth curve, indicating possible usage of the age projection tool

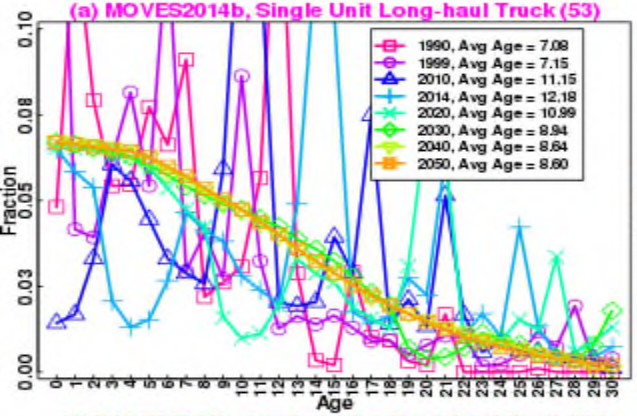
Selected Future Year Age Distributions -- Trucks (51, 52, 53, 54, 61, 62)

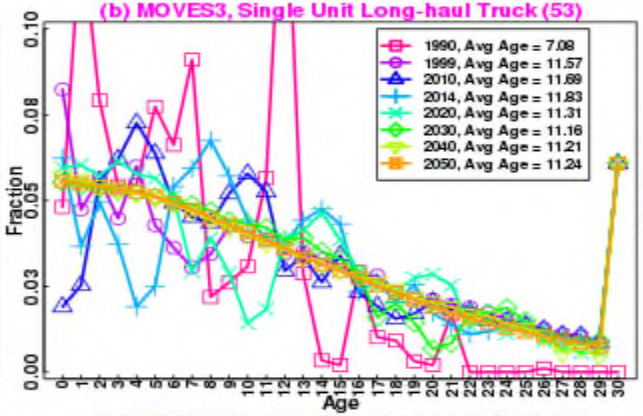


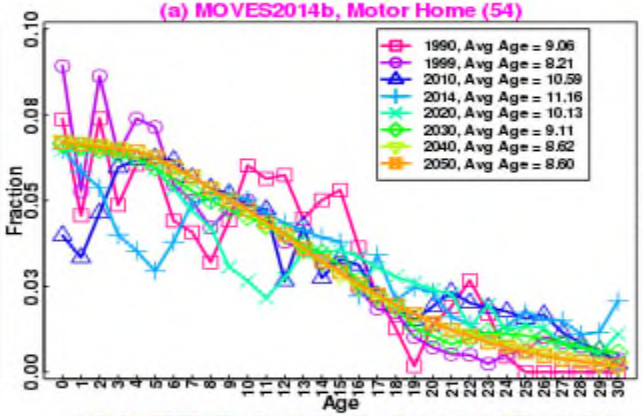


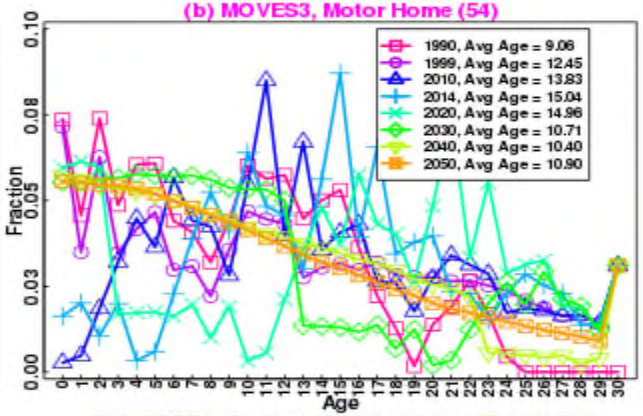


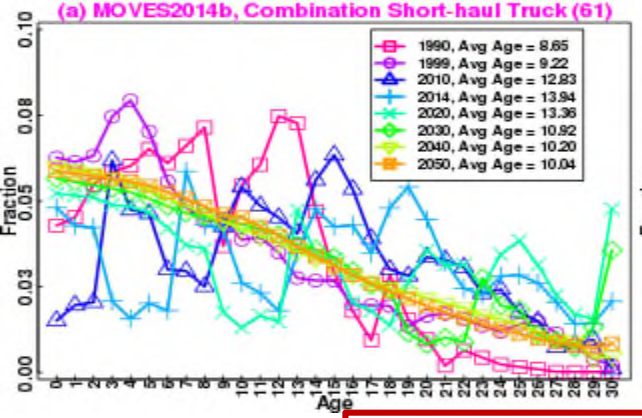


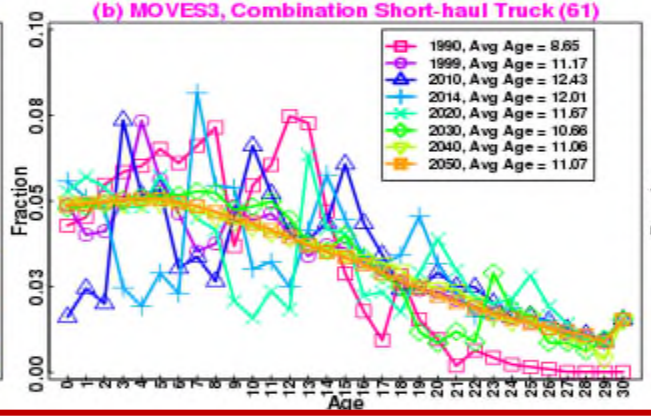


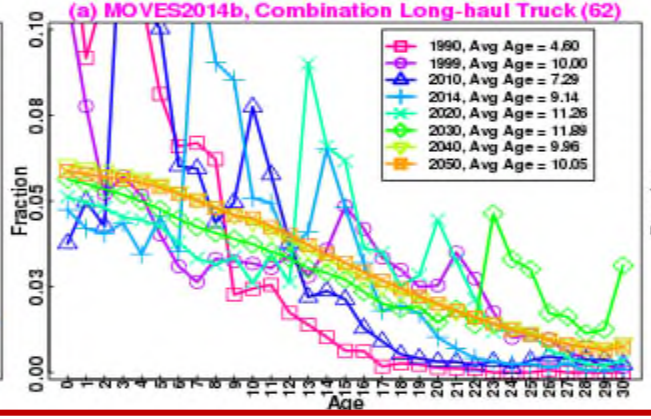


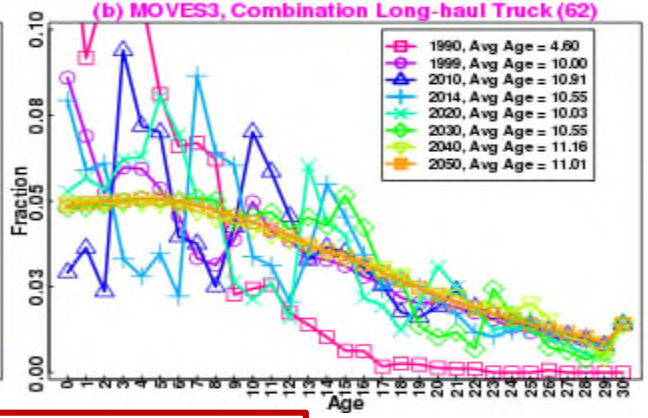












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