# Incorporation of RLINE into AERMOD

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# RLINE development

- RLINE coding, analyses, TSD documentation performed by:
  - EPA Office of Research and Development
    - David Heist
    - R. Chris Owen
  - WSP USA
    - Michelle Snyder (RLINE reformulation, RLINE-urban, RLINE terrain)
    - Laura Kent (RLINE reformulation, RLINE terrain)
    - Rebecca Miller (RLINE reformulation)
    - Melissa Buechlein (RLINE terrain)
  - Akula Venkatram
    - Initial RLINE development

# Acknowledgements


- Federal Highway Administration
  - Victoria Martinez, David Kall, George Noel, Chris Dresser
  - RLINE reformulation work for the proposal was funded in part by an Interagency Agreement between EPA and FHWA (2020-2023)
- EPA Office of Transportation of Air Quality
  - Laura Berry
  - Chad Bailey
  - Meg Patulski

# RLINE proposed source type

- RLINE proposed as additional source type in AERMOD for transportation modeling applications (e.g., transportation conformity PM hot-spot analyses)
  - BETA keyword needed with MODELOPT keyword
- Addition of RLINE source ***would not*** preclude the use of the other source types (AREA, LINE, VOLUME) for transportation source modeling
- Proposed that AERMOD's urban option be applicable to the RLINE source type
- Proposed that terrain effects be applicable to the RLINE source type
  - ***Would not*** supersede EPA's Hot-spot guidance where FLAT terrain is recommended for mobile source modeling applications.
  - See "Evaluation of Addition of Terrain Treatment to the RLINE Source Type in AERMOD" Technical Support Document for more information
- This presentation will focus on the RLINE reformulation detailed in the Technical Support Document "Incorporation and Evaluation of the RLINE Source Type in AERMOD for Mobile Source Applications"

# History of RLINE development

- Based on ORD's Research Line Model released in 2013
  - Snyder et al., 2013; Venkatram et al., 2013
- RLINE model incorporated into AERMOD in version 19191 as the beta RLINE source type
- Based on collaborative effort between EPA and FHWA, RLINE reformulated as part of the 23132 release with three main modification areas:
  - Wind speed calculation
  - Harmonization of AERMOD internal processing with other AERMOD source types
  - Updates to dispersion coefficients for $\sigma_y$ and $\sigma_z$

# Wind speed modification

- RLINE model developed with assumption of input vector average wind speed and converted to scalar average speed within model
- When RLINE was initially incorporated into AERMOD, conversion not needed as AERMOD input wind speeds are scalar averages for the most part (i.e., airport data)
- Correction made in code to ensure that the advecting wind speed (based on Monin-Obukhov Similarity Theory) does not fall below the minimum wind speed enforced by RLINE

# Harmonization with other AERMOD source types

- To better integrate RLINE within AERMOD, several changes made to use native AERMOD functions when possible
  - RLINE now uses the gridded values of $\sigma_v$ used by other AERMOD source types
    - Prior to AERMOD 23132 RLINE calculated its own value of $\sigma_v$
  - RLINE uses the AERMOD functions to calculate fraction of plume attributed to meander
  - Calculation of vertical plume width $\sigma_z$
    - Prior to AERMOD 23132, $\sigma_z$ growth limited to $\sqrt{2/\pi}$ zi (zi = mixing height)
    - With 23132, restriction removed and RLINE uses AERMOD functions to account for reflections of plume from the ground and top of the mixed layer

# Dispersion Coefficients

- As a result of the wind speed modification and harmonization changes, coefficients in the calculations of $\sigma_y$ and $\sigma_z$ in RLINE were re-evaluated and modified
- Optimization of coefficients occurred together
- Based on datasets collected in Idaho Falls and Prairie Grass studies
- See RLINE Technical Support Document Section 2.3 for details

# Dispersion Coefficients for $\sigma_y$ and $\sigma_z$

$$\sigma_y = c\frac{\sigma_v}{u_*}\sigma_z\left(1 + d_s\frac{\sigma_z}{L}\right)$$ L > 0.0 (stable)

$$\sigma_y = c\frac{\sigma_v}{u_*}\sigma_z\left(1 + d_u\frac{\sigma_z}{|L|}\right)^{-1/2}$$ L < 0.0 (convective)

$$\sigma_z = a\frac{u_*}{u_{eff}}x\left(1 + b_s\frac{u_*}{u_{eff}}\left(\frac{x}{|L|}\right)^{2/3}\right)^{-1}$$ L > 0.0 (stable)

$$\sigma_z = a\frac{u_*}{u_{eff}}x\left(1 + b_u\frac{u_*}{u_{eff}}\frac{x}{|L|}\right)$$ L < 0.0 (convective)

# Dispersion coefficients

| Coefficient | Original Value (Venkatram et al., 2013) | Range Tested | New Value |
|---|---|---|---|
| a | 0.57 | 0.4 - 1.0 | 0.7 |
| $b_s$ | 3.0 | 0.5 - 4.0 | 1.5 |
| $b_u$ | 1.5 | 0.5 - 2.0 | 1.0 |
| c | 1.6 | 1.0 – 5.0 | 1.4 |
| $d_s$ | 2.5 | -2.5 – 2.5 | 1.5 |
| $d_u$ | 1.0 | 2.0 - 3.5 | 2.5 |

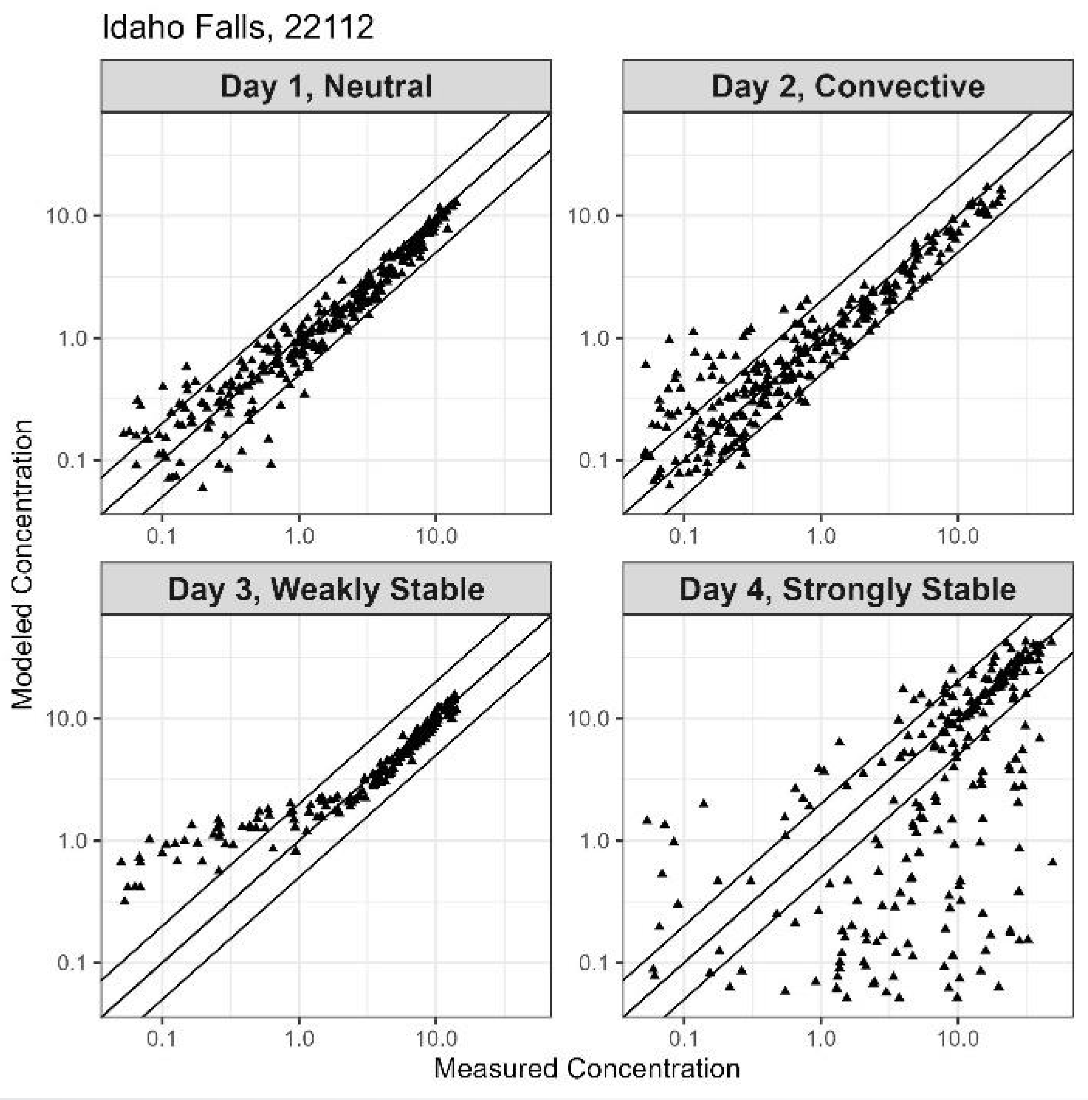
# Evaluations

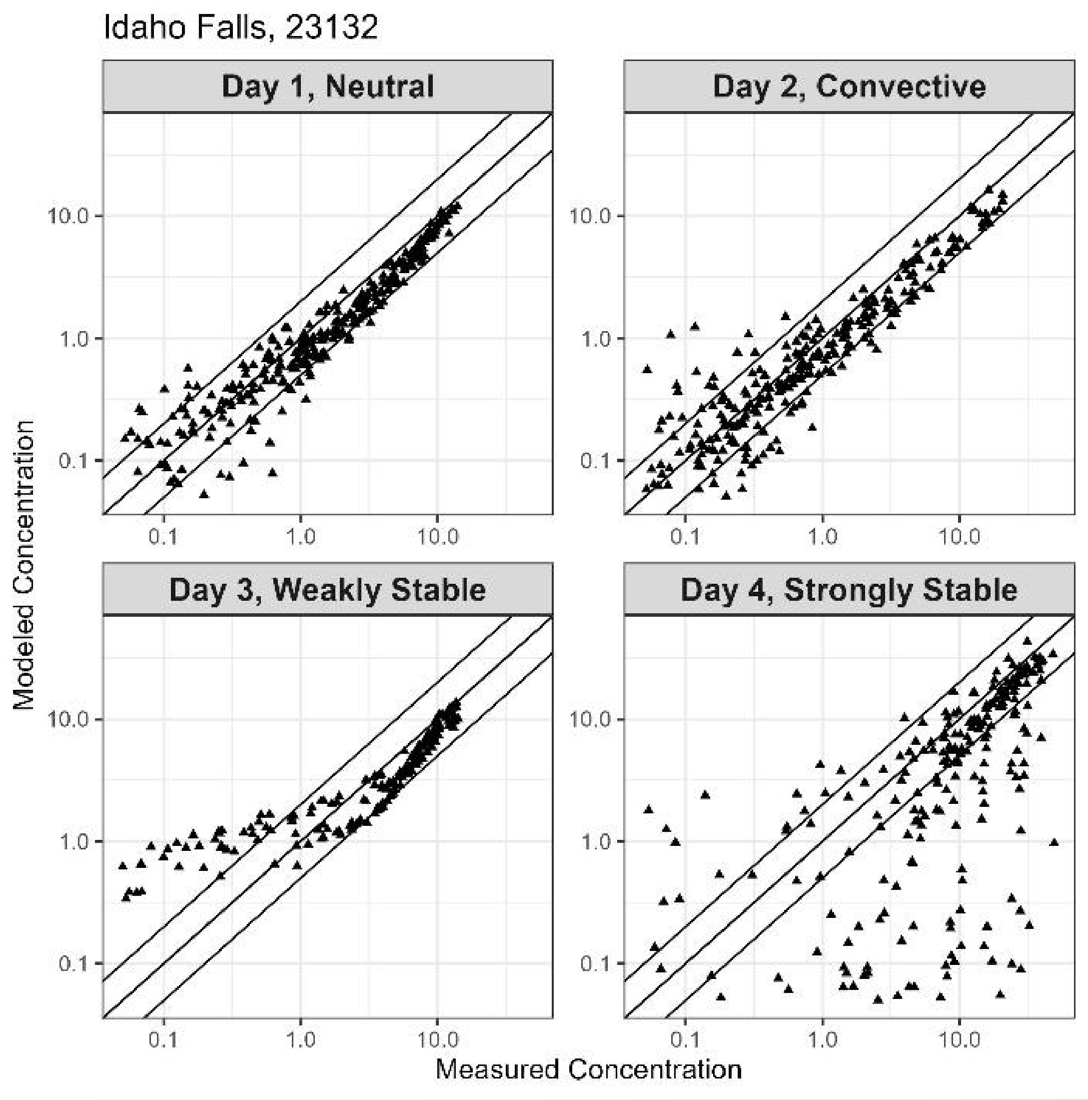
- Comparisons of RLINE in AERMOD 22112 and AERMOD 23132 (reformulated version)
  - Idaho Falls Roadway Study
  - Caltrans 99 Highway Study
  - GM Sulfate Dispersion Experiment
  - Hot-spot model intercomparisons
    - Analysis A: $PM_{2.5}$ analysis
    - Analysis B: $PM_{10}$ analysis
    - Analyses A and B used airport meteorological data with standard AERMET processing
- See RLINE Reformulation TSD, Section 3.0 for details on each study area

# Idaho Falls

- Only small changes in model performance, especially for neutral and convective days
- For the weakly stable day, highest concentrations remain relatively unchanged,
  - though agreement between measured and modeled concentrations is reduced somewhat for concentrations on lower end of distribution.
- For the strongly stable day, highest overpredictions in AERMOD 22112 have been reduced in AERMOD 23132

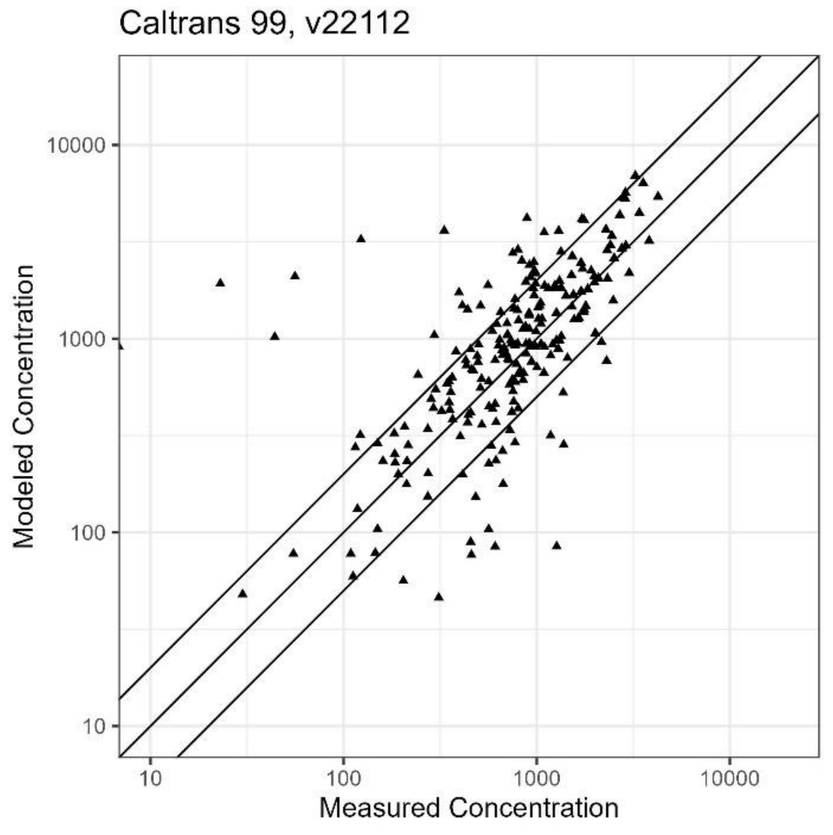
# Idaho Falls SF6 concentrations (ppb)

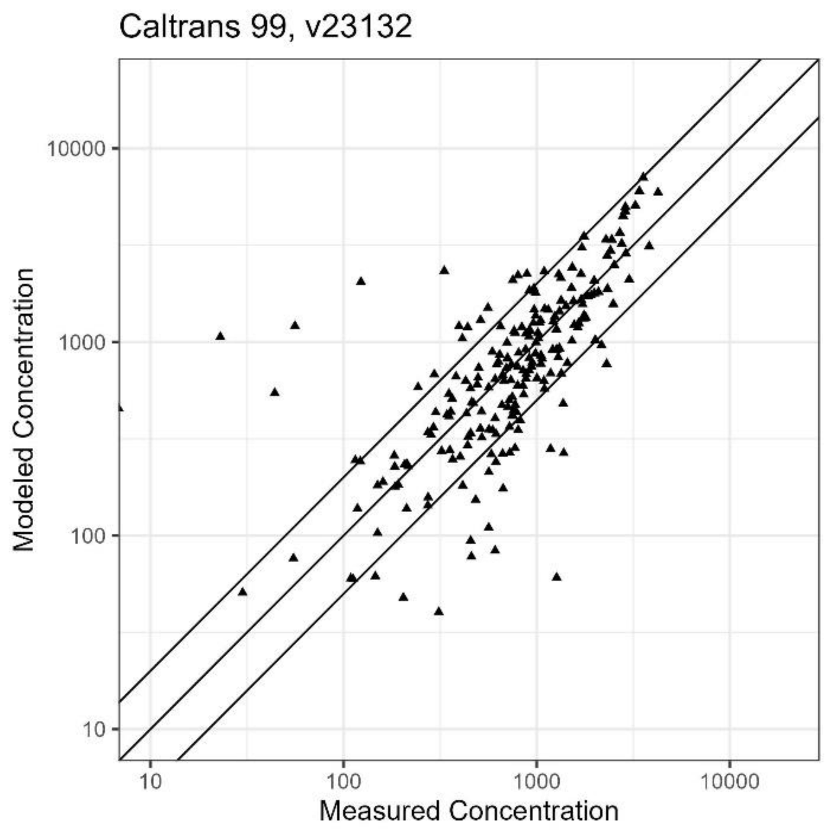


# Caltrans 99

- Minor differences between AERMOD 22112 and AERMOD 23132
  - Most notable change is reduction in concentration for the five outliers in upper left part of plots

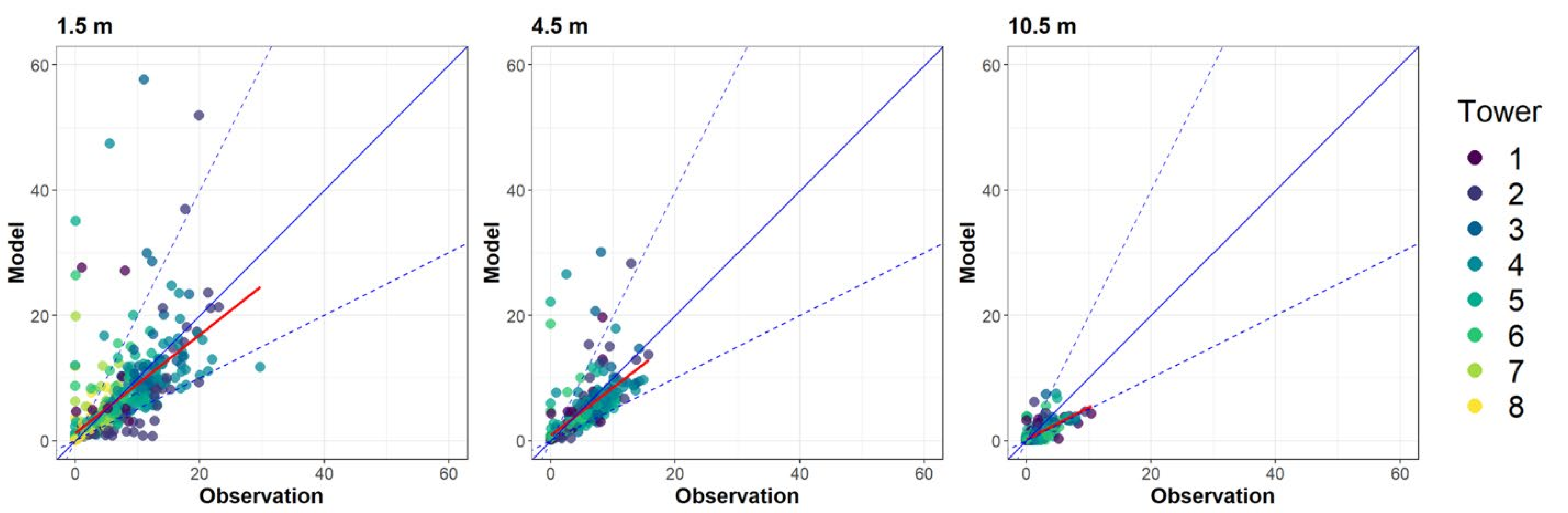


# GM Sulfate

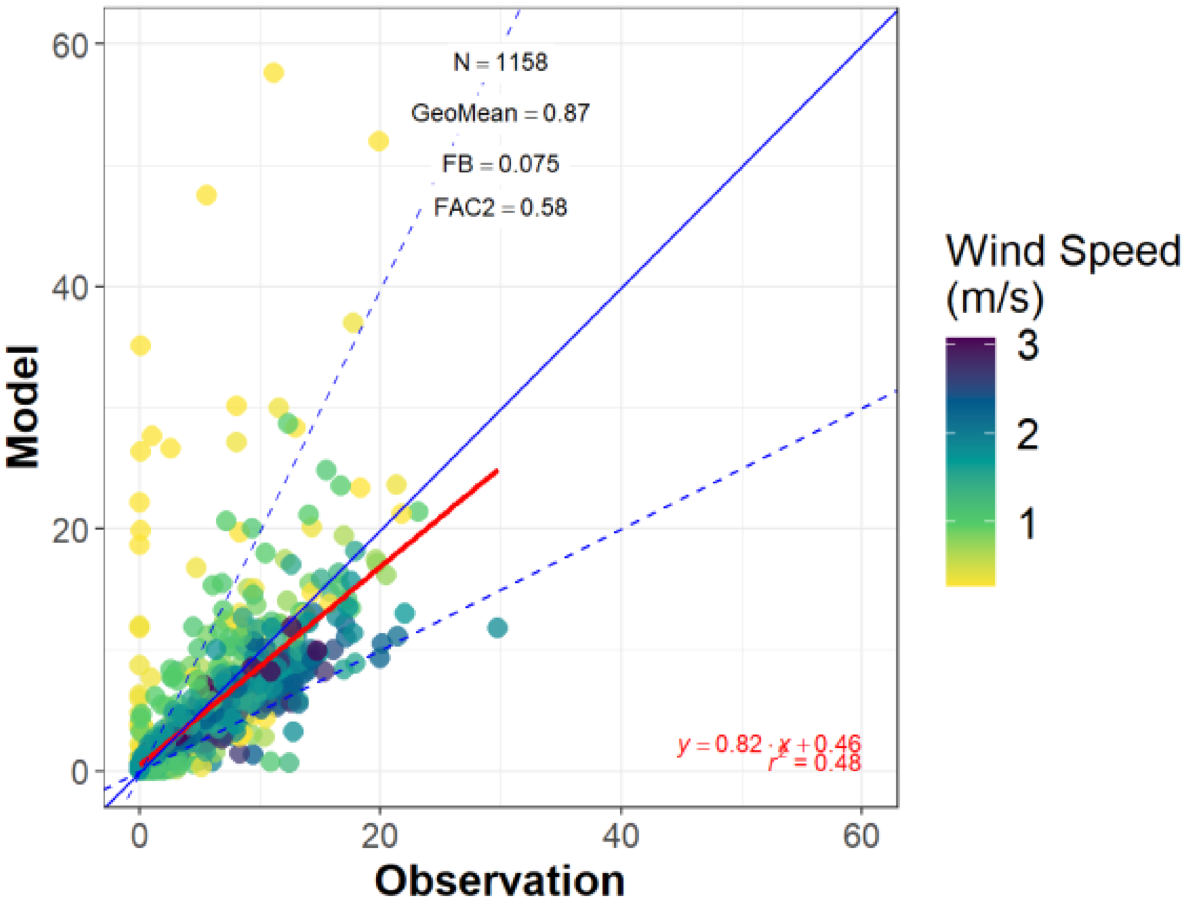
- RLINE predicts concentrations at a reasonable level
  - On average, slight underprediction with a few overpredictions, greater than factor of 2.
  - Overpredictions at 1.5 and 4.5 m heights with wind speeds < 1 m/s and winds out of North to ENE; could be periods with wind blowing parallel to roadway instead of perpendicular.
  - Further investigation needed

# GM Sulfate

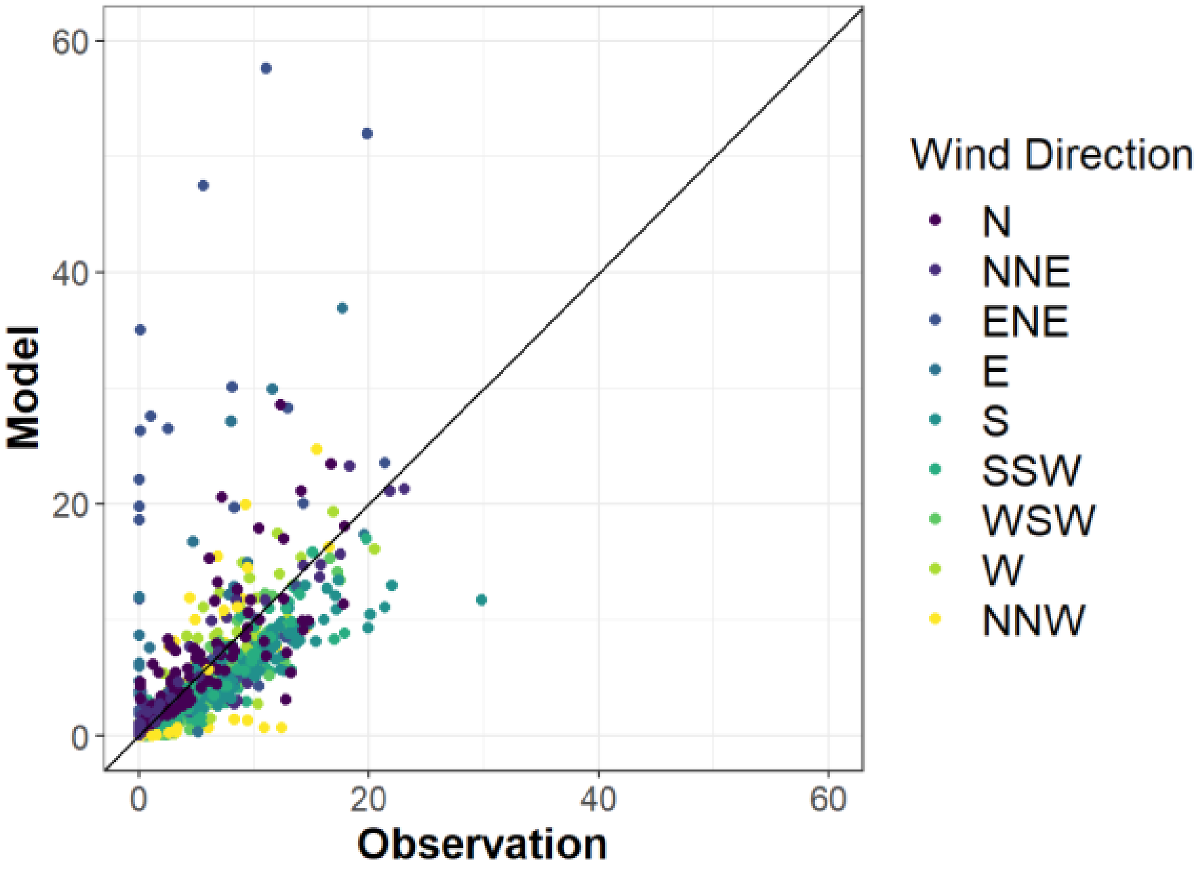



Concentrations by measurement height (μg/m$^3$)

# GM Sulfate




Concentrations by wind speed(μg/m³)



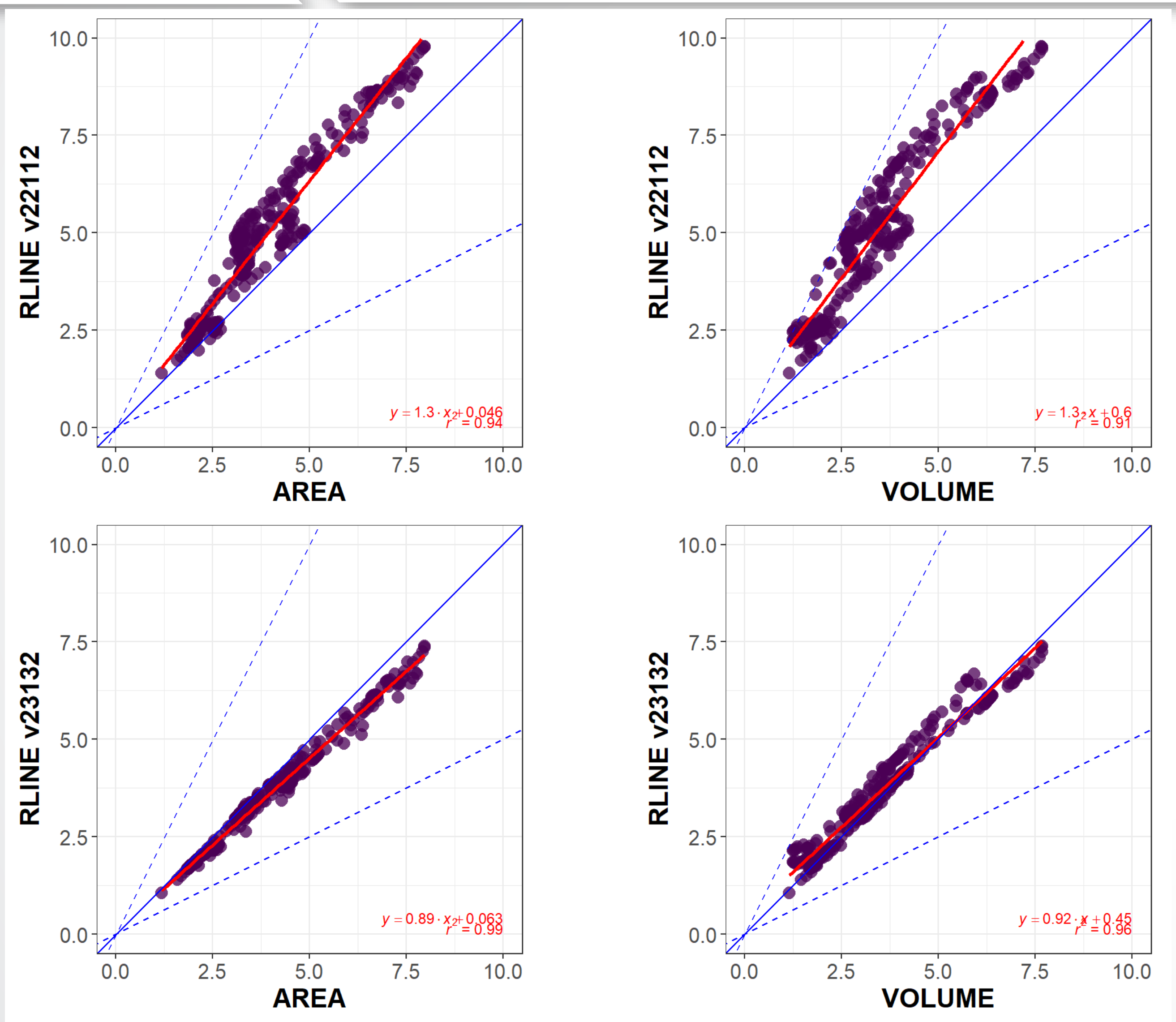

Concentrations by wind direction(μg/m³)

# $PM_{2.5}$ hot-spot

$PM_{2.5}$ maximum design concentrations (μg/m$^3$)

| Source Type | v22112 H8H 24-hr | v23132 H8H 24-hr | v22112 Annual | v23132 Annual |
|---|---|---|---|---|
| RLINE | 9.78 | 7.40 | 3.72 | 3.20 |
| VOLUME | 7.69 | | 3.30 | |
| AREA | 7.97 | | 2.93 | |

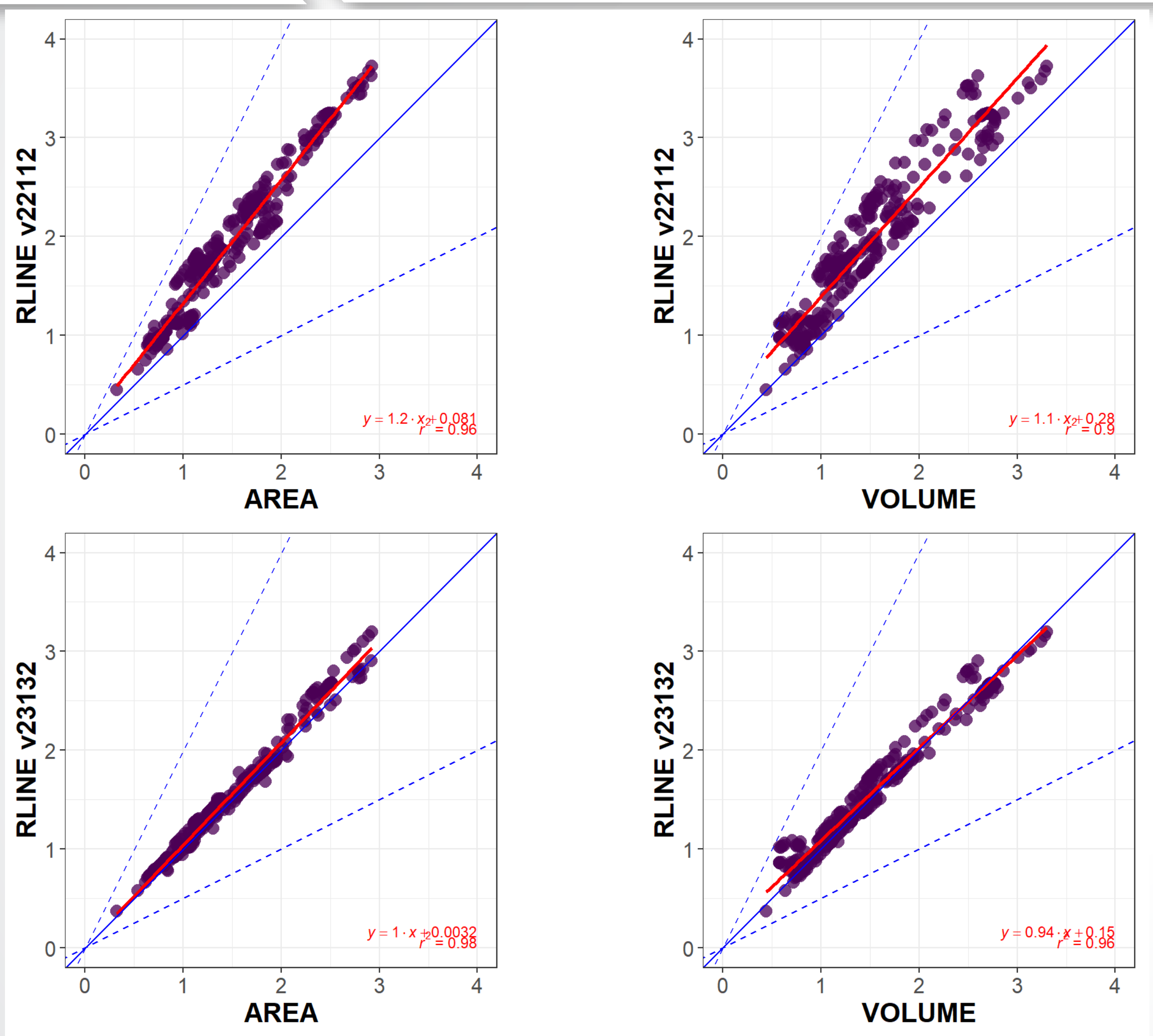
# PM$_{2.5}$ hot-spot




## PM$_{2.5}$ 24-hour design concentrations (µg/m$^3$) by receptor: RLINE compared to other source types

- RLINE v22112 overpredicts compared to AREA and VOLUME
- RLINE v23132 slight underprediction compared to AREA and good agreement with VOLUME

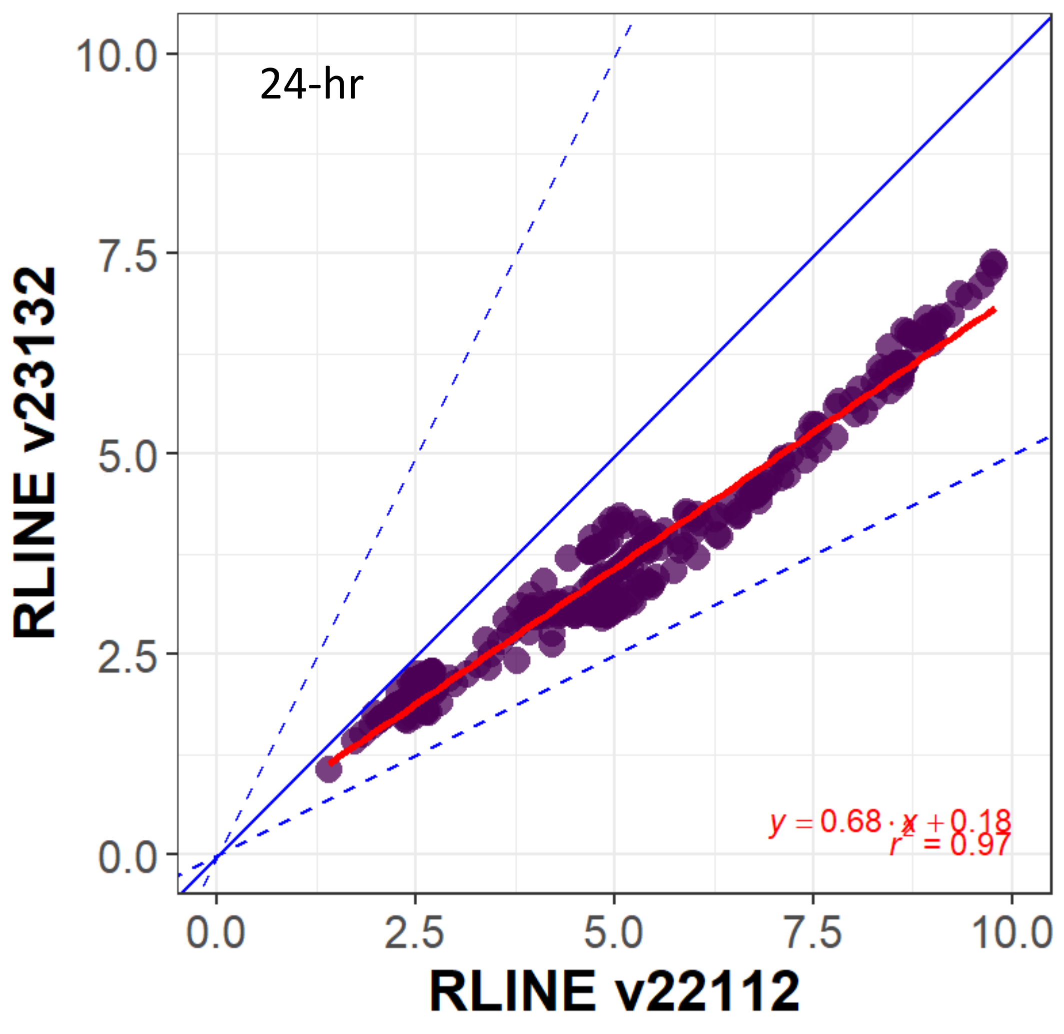
# $PM_{2.5}$ hot-spot

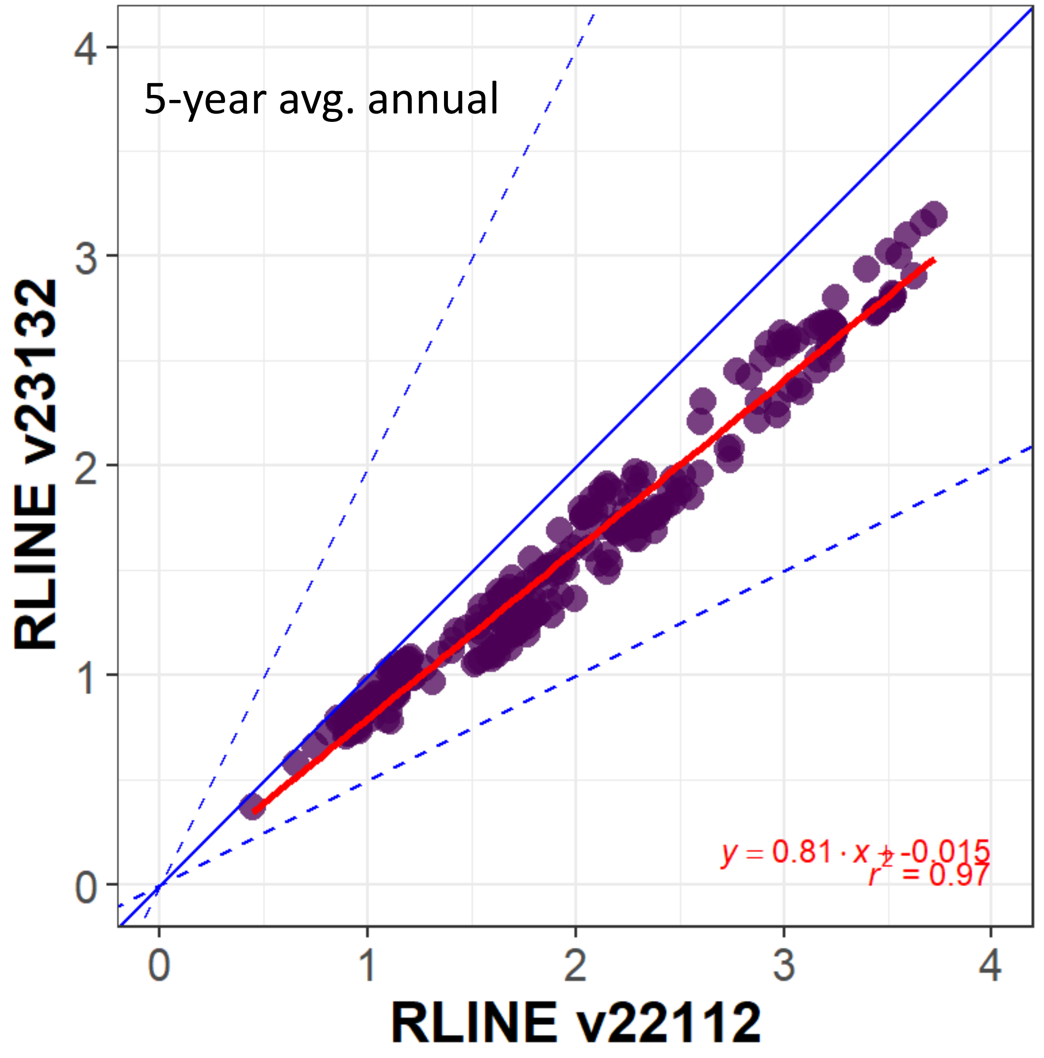



## $PM_{2.5}$ annual design concentrations (µg/m$^3$) by receptor: RLINE compared to other source types

- RLINE v22112 overpredicts compared to AREA and VOLUME
- RLINE v23132 compares well with both AREA and VOLUME

# $PM_{2.5}$ hot-spot



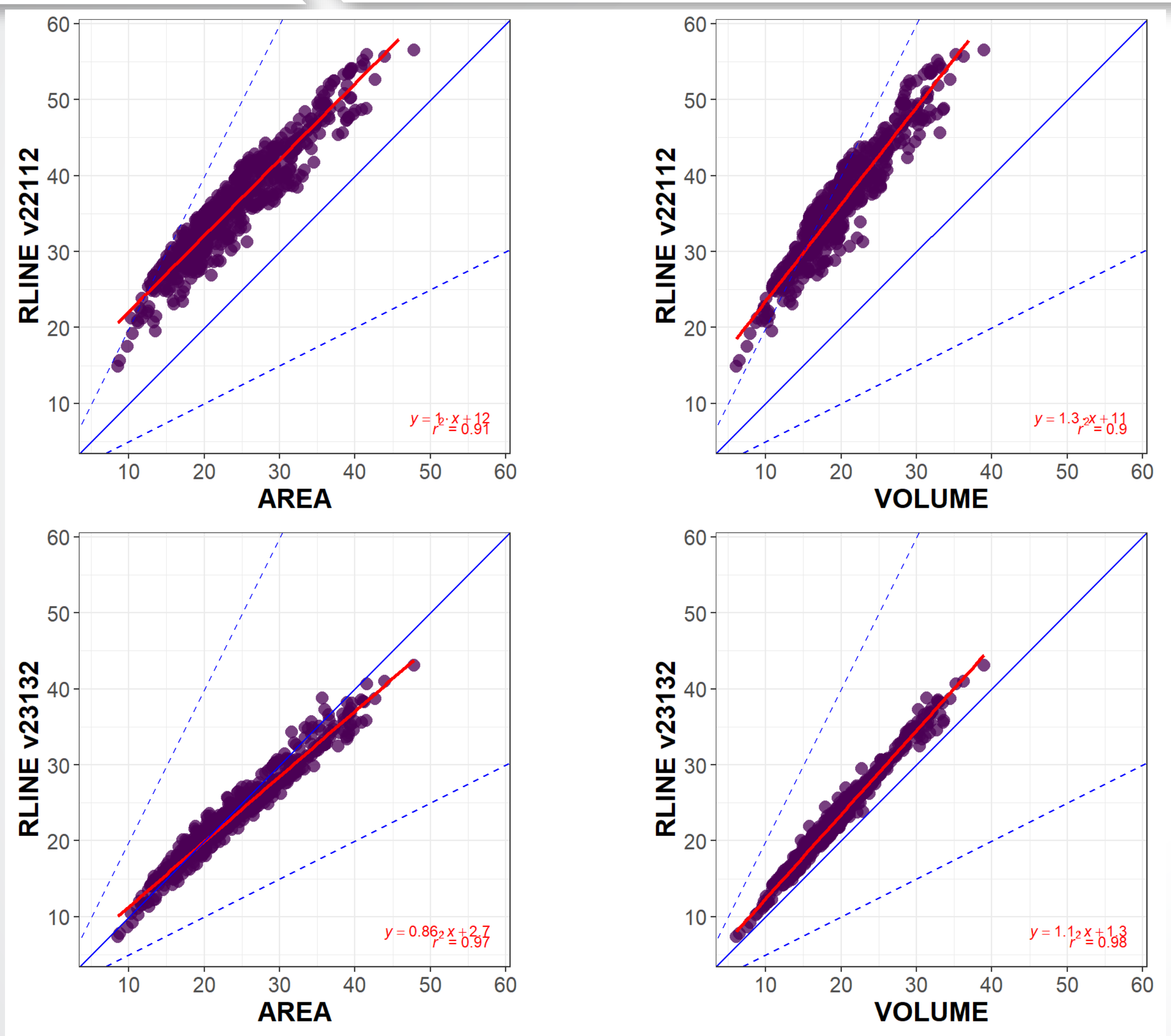



# $PM_{10}$ hot-spot

$PM_{10}$ maximum design concentrations ($\mu g/m^3$)

| **Source Type** | **v22112 H6H 24-hr** | **v23132 H6H 24-hr** |
|---|---|---|
| RLINE | 56.54 | 43.12 |
| VOLUME | 38.98 | |
| AREA | 47.79 | |

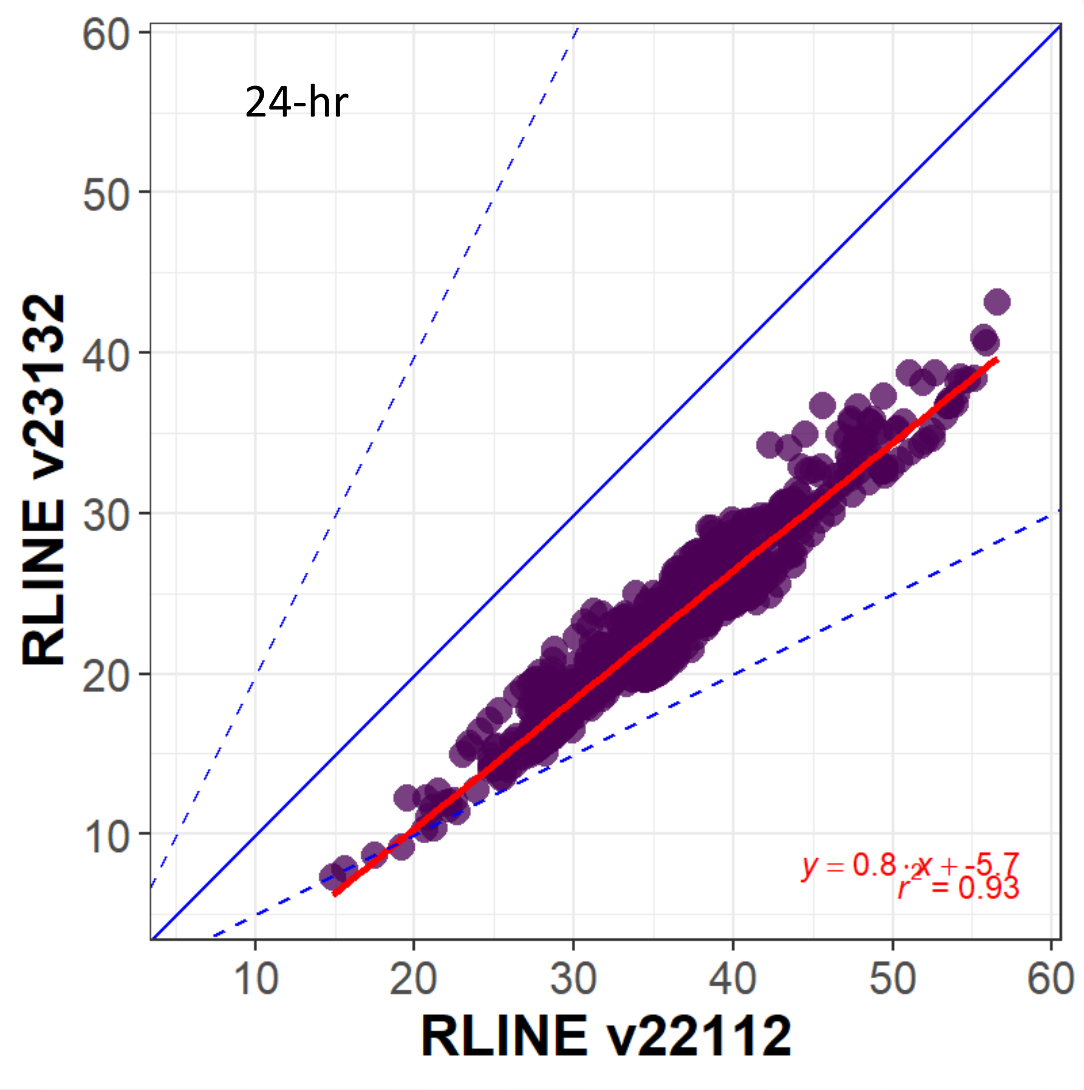
# $PM_{10}$ hot-spot




## $PM_{10}$ 24-hour design concentrations (μg/m$^3$) by receptor: RLINE compared to other source types

- RLINE v22112 overpredicts compared to AREA and VOLUME
- RLINE v23132 good agreement with AREA, slight overprediction compared to VOLUME

# $PM_{10}$ hot-spot



# Summary/Conclusions

- Idaho Falls and Caltrans 99 show decrease in concentrations with RLINE reformulation in AERMOD 23132 vs. AERMOD 22112
- GM Sulfate shows good agreement to observations for reformulation
- Hot-spot analyses show drop in RLINE concentrations with reformulation with reformulated concentrations falling between AREA and VOLUME source concentrations
- RLINE shows good performance overall

- Proposal to include RLINE as a source type would give modelers additional flexibility for defining transportation links within AERMOD