# Contribution of Chemical Constituents to Visibility Reduction During the California Regional PM10/PM2.5 Air Quality Study

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# Approach

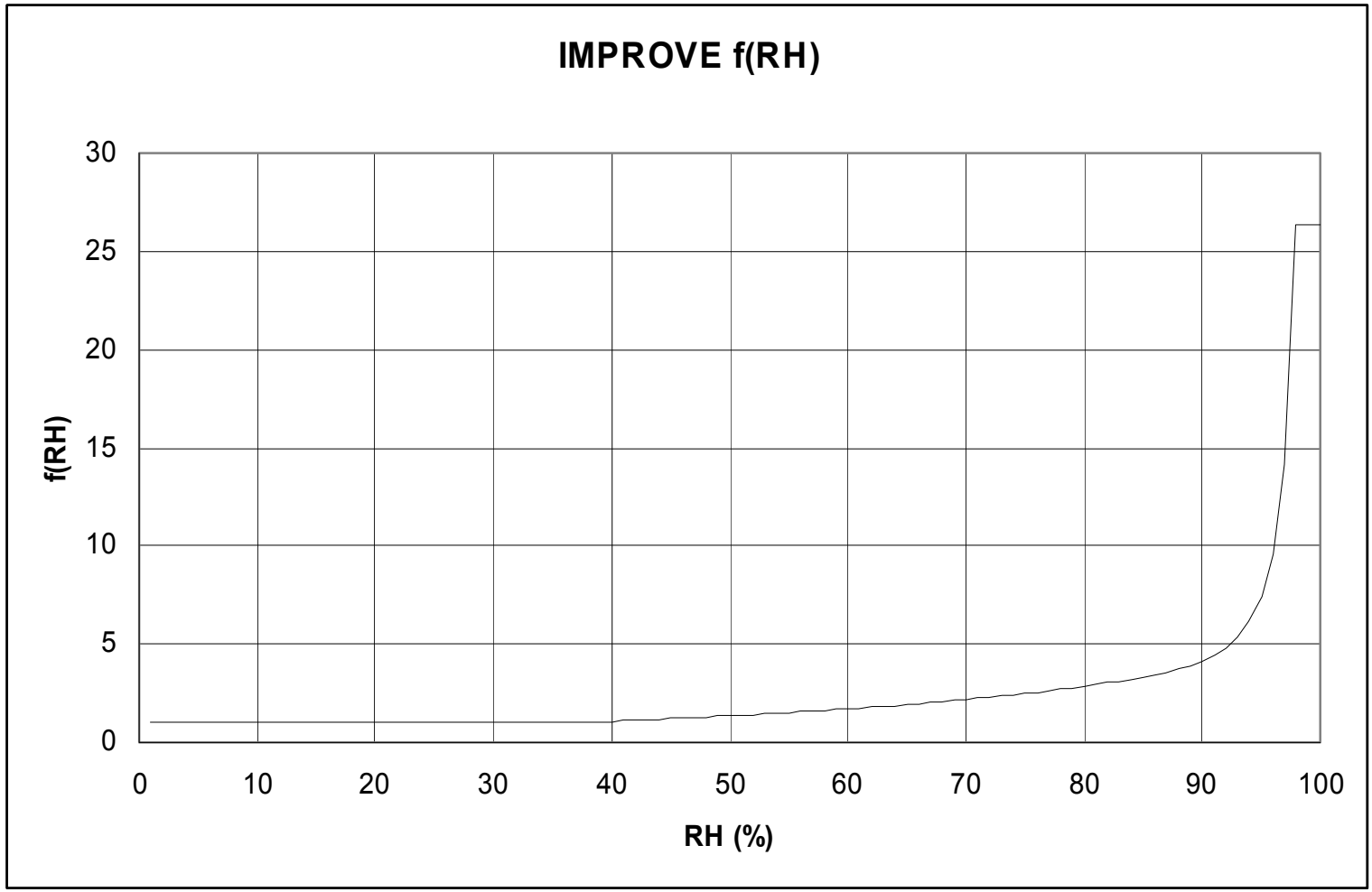
- Applied light extinction efficiencies to 24-hour average particulate matter chemical composition data to estimate constituent contributions to the light extinction coefficient
- Constituents included:
  Fine Soil = 1.89[Al] + 2.14[Si] +1.4[Ca] + 1.43[Fe]
  $NH_4NO_3$ = 1.29[$NO_3^-$]
  $(NH_4)_2SO_4$ = 1.375[$SO_4^=$]
  Organic Compounds (OCM) = 1.4[OC]
  Elemental Carbon (EC) = measured EC

# Light Extinction Efficiencies

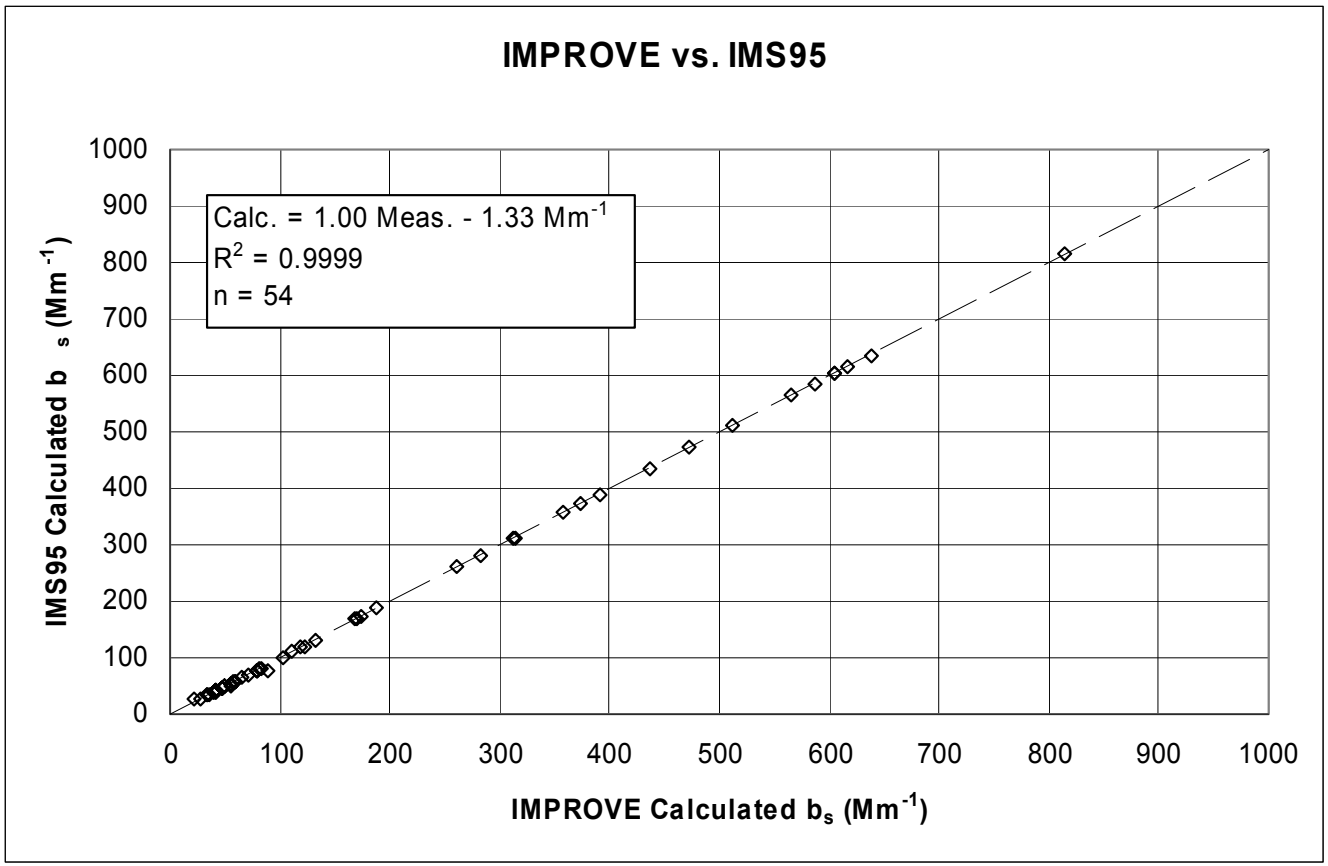
- Used 10 $m^2/g$ for light absorption by EC
- Evaluated light scattering efficiencies developed for IMS95 and for IMPROVE (Interagency Monitoring of Protected Visual Environments) with 24-hour average chemical composition, light scattering coefficient ($b_s$), and relative humidity (RH) data from Fresno First Street (FSF) site
- Chose FSF data because only site with open-air, unheated nephelometer (NGN-2)

# IMS95 and IMPROVE Light Scattering Efficiencies

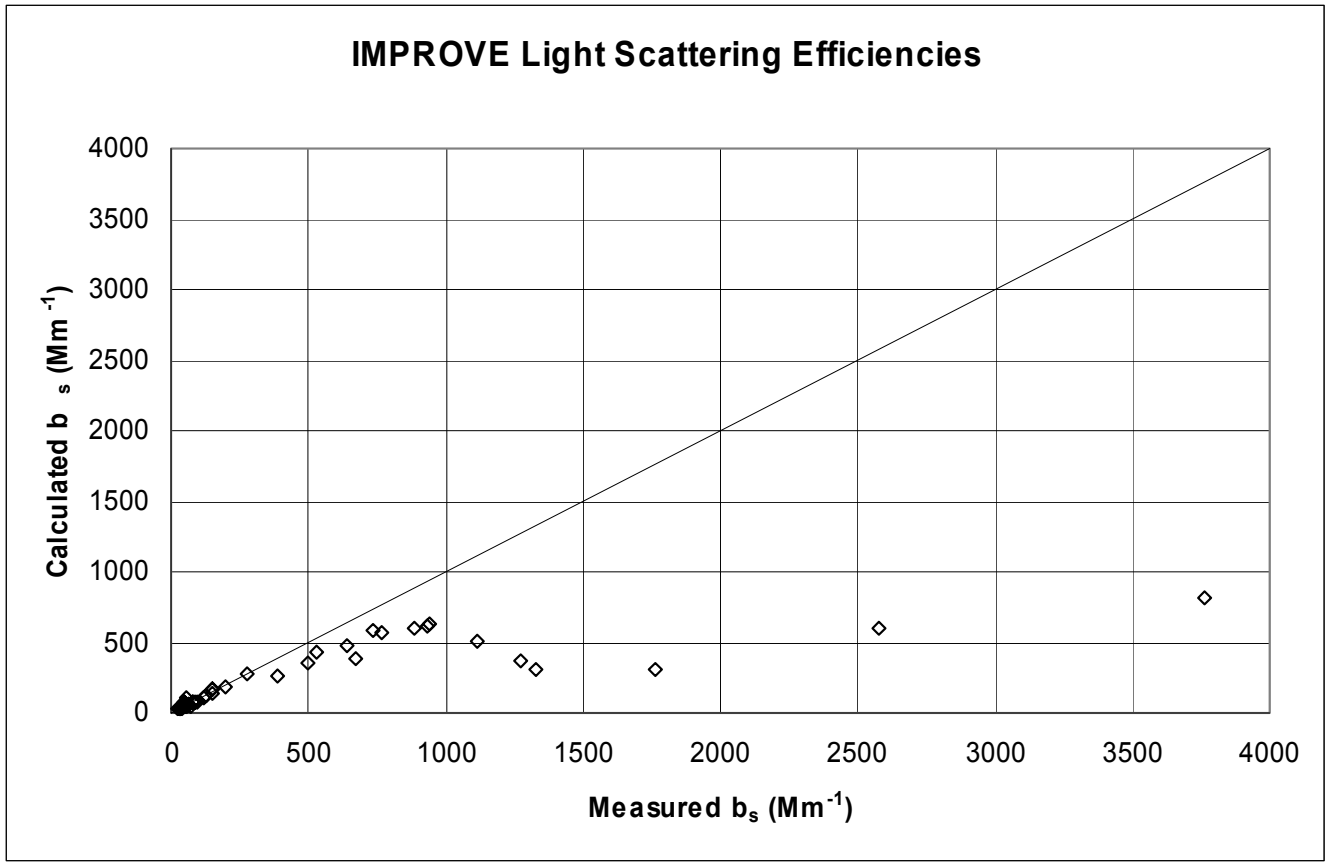
| **Constituent** | **IMS95 ($m^2/g$)** | **IMPROVE ($m^2/g$)** |
|---|---|---|
| Fine Soil | 2 | 1 |
| $NH_4NO_3$ | $2.1/(1\text{-}RH)^{0.7}$ | 3f(RH) |
| $(NH_4)_2SO_4$ | $2.1/(1\text{-}RH)^{0.7}$ | 3f(RH) |
| OC | $2.8/(1\text{-}RH)^{0.2}$ | 4 |


IMPROVE f(RH)
30
25
20
15
10
5
0
f(RH)
0
10
20
30
40
50
60
70
80
90
100
RH (%)

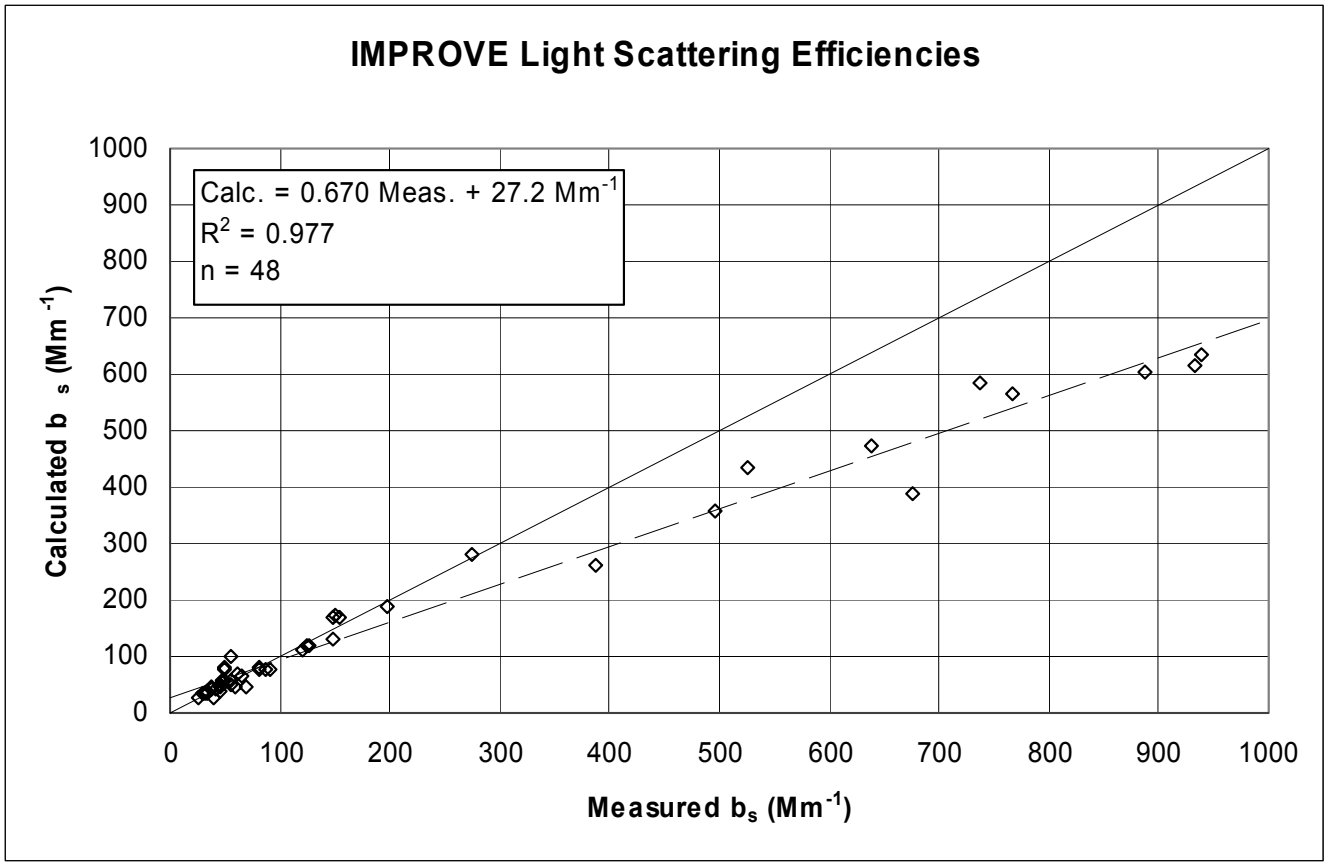
# IMS95 and IMPROVE Efficiencies Produced Essentially Identical Results



# Measured $b_s$ is Under-predicted, Especially at High Values



# Correlation is Good at Lower Values, but Measured $b_s$ is Under-Predicted



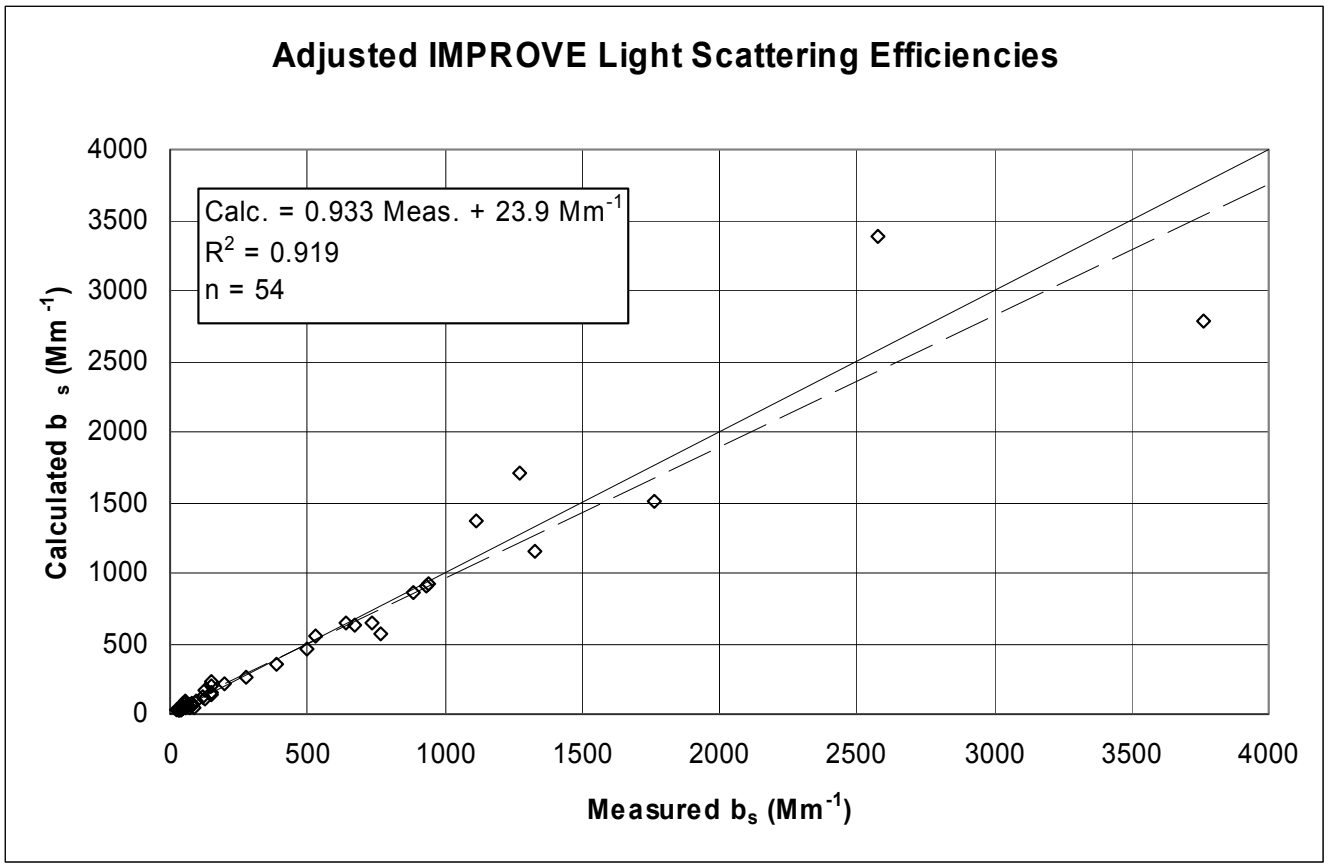
# Calculated Seasonal Adjustments to IMPROVE Efficiencies

- Only adjusted efficiencies for $NH_4NO_3$ and $(NH_4)_2SO_4$
- Seasonal adjustment calculated as average of:
  (measured $b_s$ - soil $b_s$ - OCM $b_s$) /
  ($NH_4NO_3$ $b_s$ + $(NH_4)_2SO_4$ $b_s$)
- Also calculated adjustment factor for high light scattering (measured $b_s$ > 1000 $Mm^{-1}$)

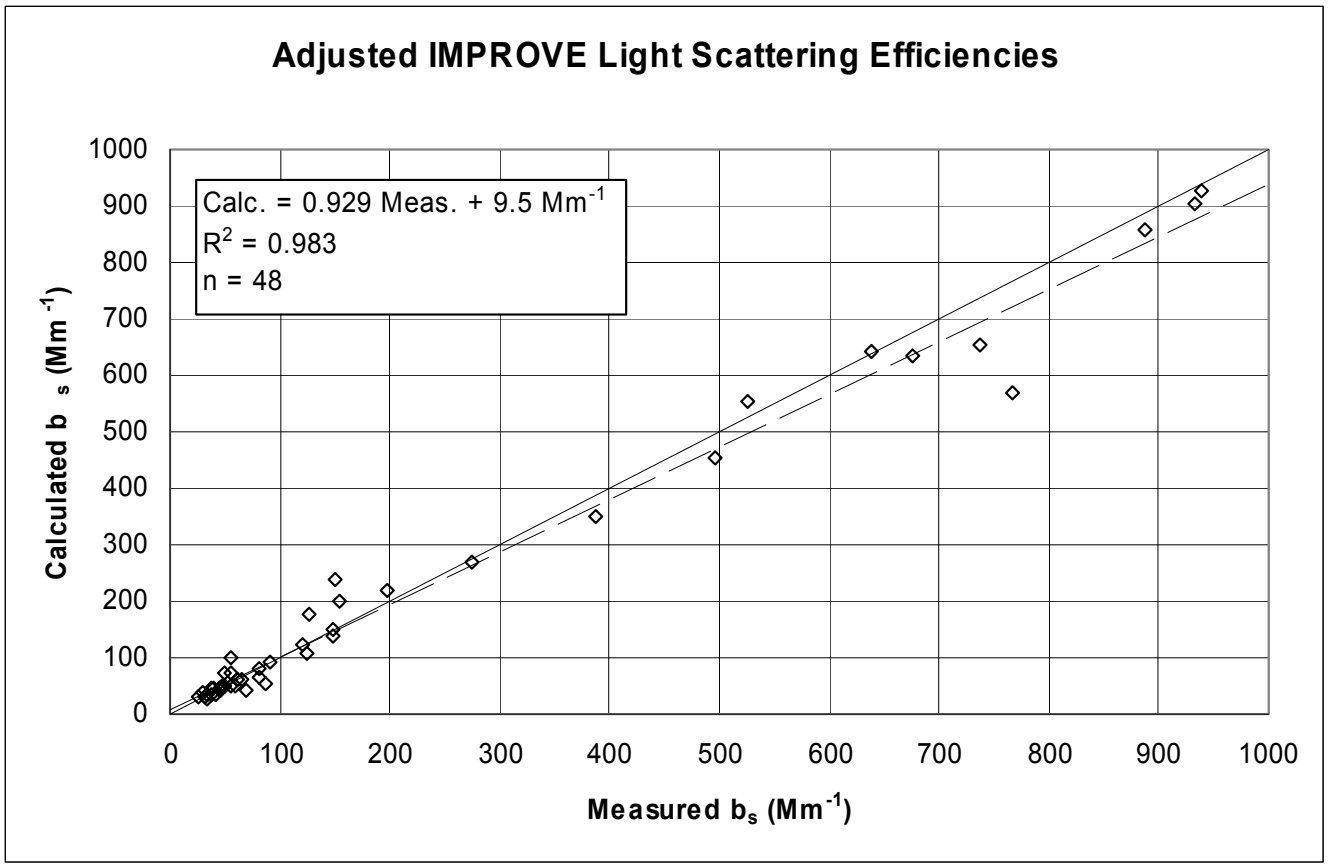
# $NH_4NO_3$ and $(NH_4)_2SO_4$ Light Scattering Efficiency Adjustment Factors

| **Season** | **Adjustment Factor** |
|---|---|
| Winter (Dec. – Feb.) | 2.17 |
| Spring (Mar. – May) | 0.74 |
| Summer (Jun. – Aug.) | 0.81 |
| Fall (Sep. – Nov.) | 1.51 |
| High Measured $b_s$ | 5.09 |

# Adjustment Improves Agreement

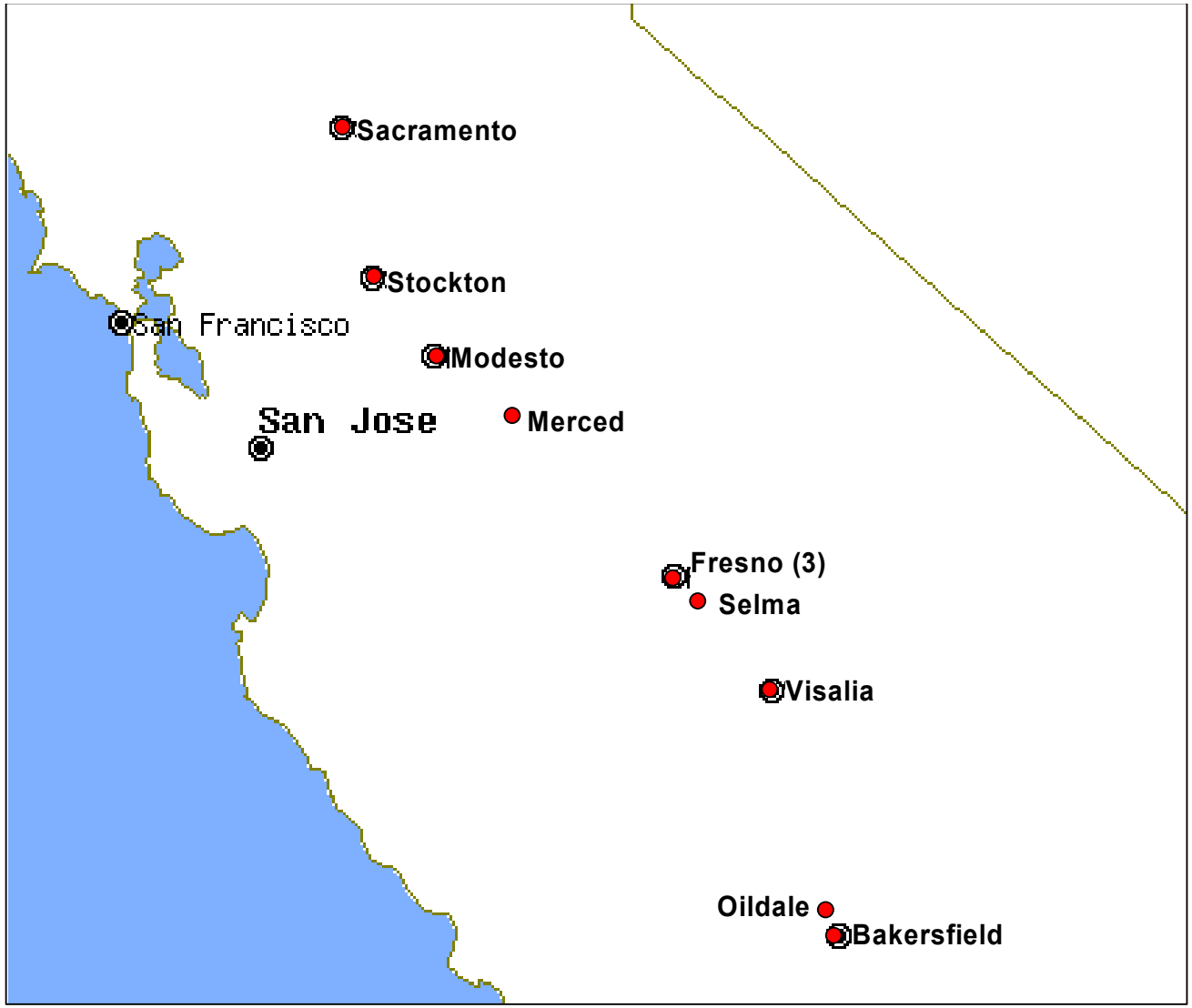


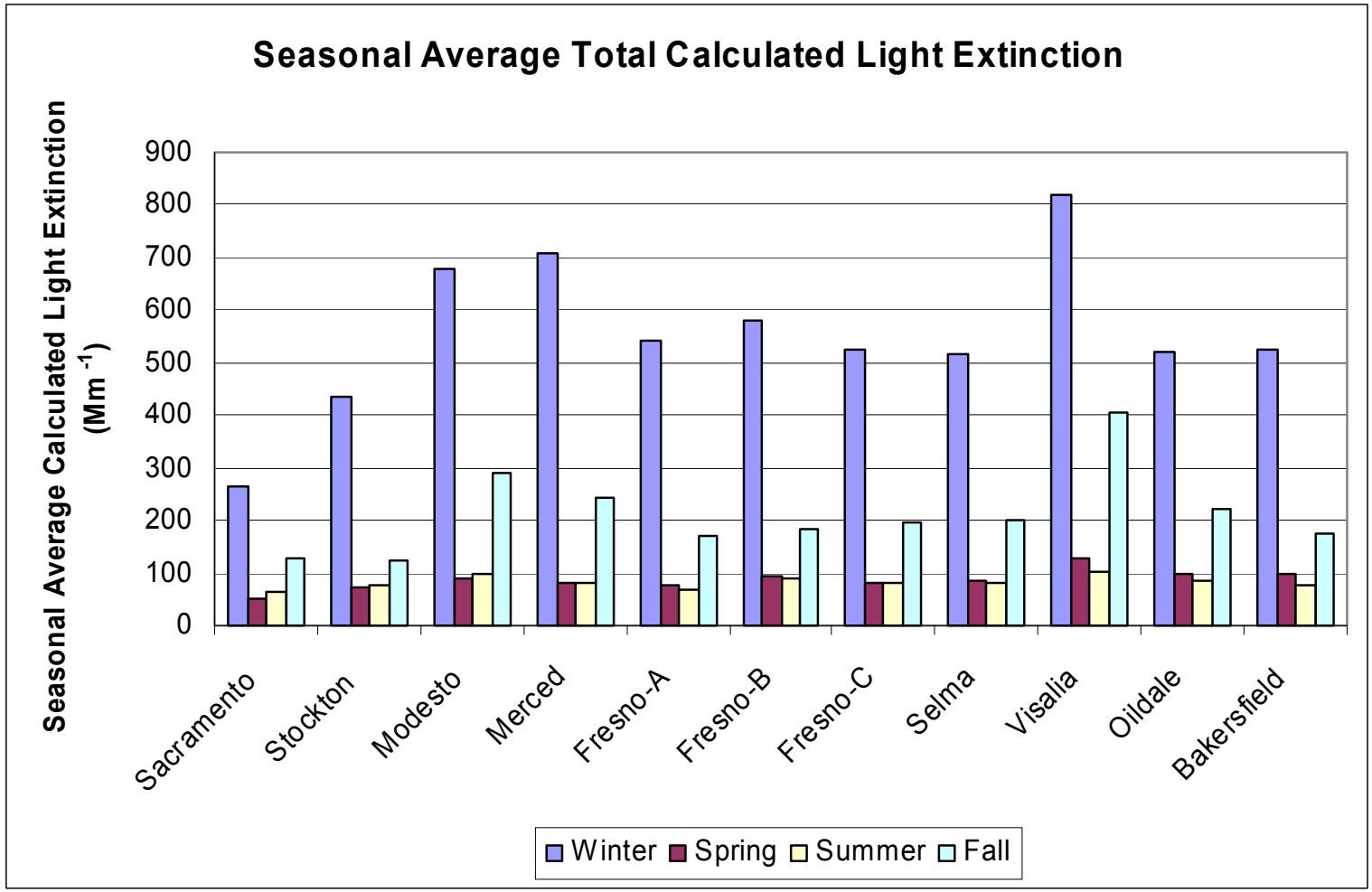
# Agreement Is Best at Lower Values



# Application of Light Extinction Efficiencies

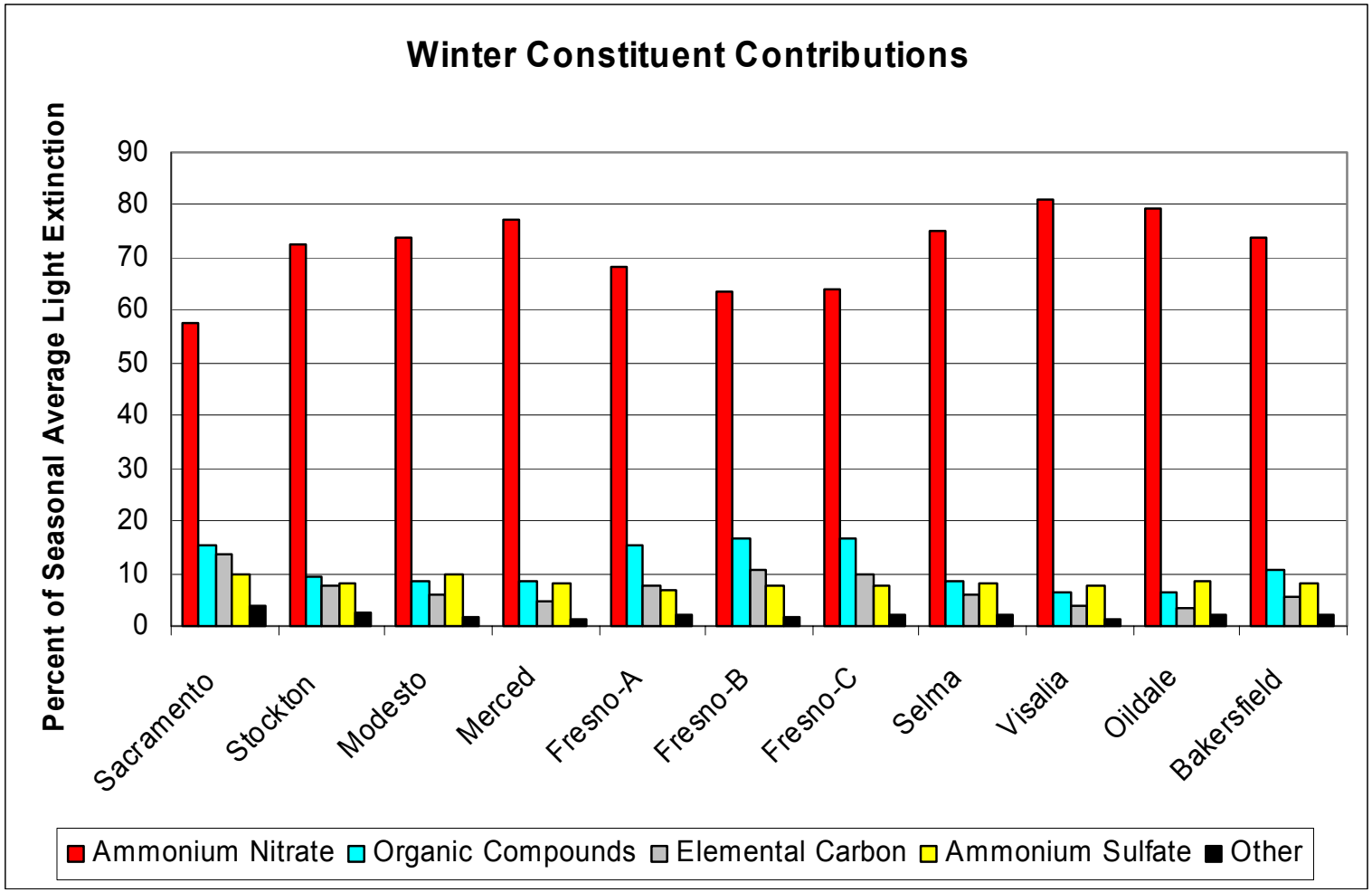
- Applied to 11 sites with annual relative humidity and PM2.5 chemical composition data
- Data available from 12/99 - 1/01
- Calculated f(RH) for every hour and averaged over 24-hour filter sampling periods
- “Capped” f(RH) at value for 95% relative humidity to avoid “instabilities”
- Did not apply adjustment for “high” values (i.e., only used seasonal adjustment)

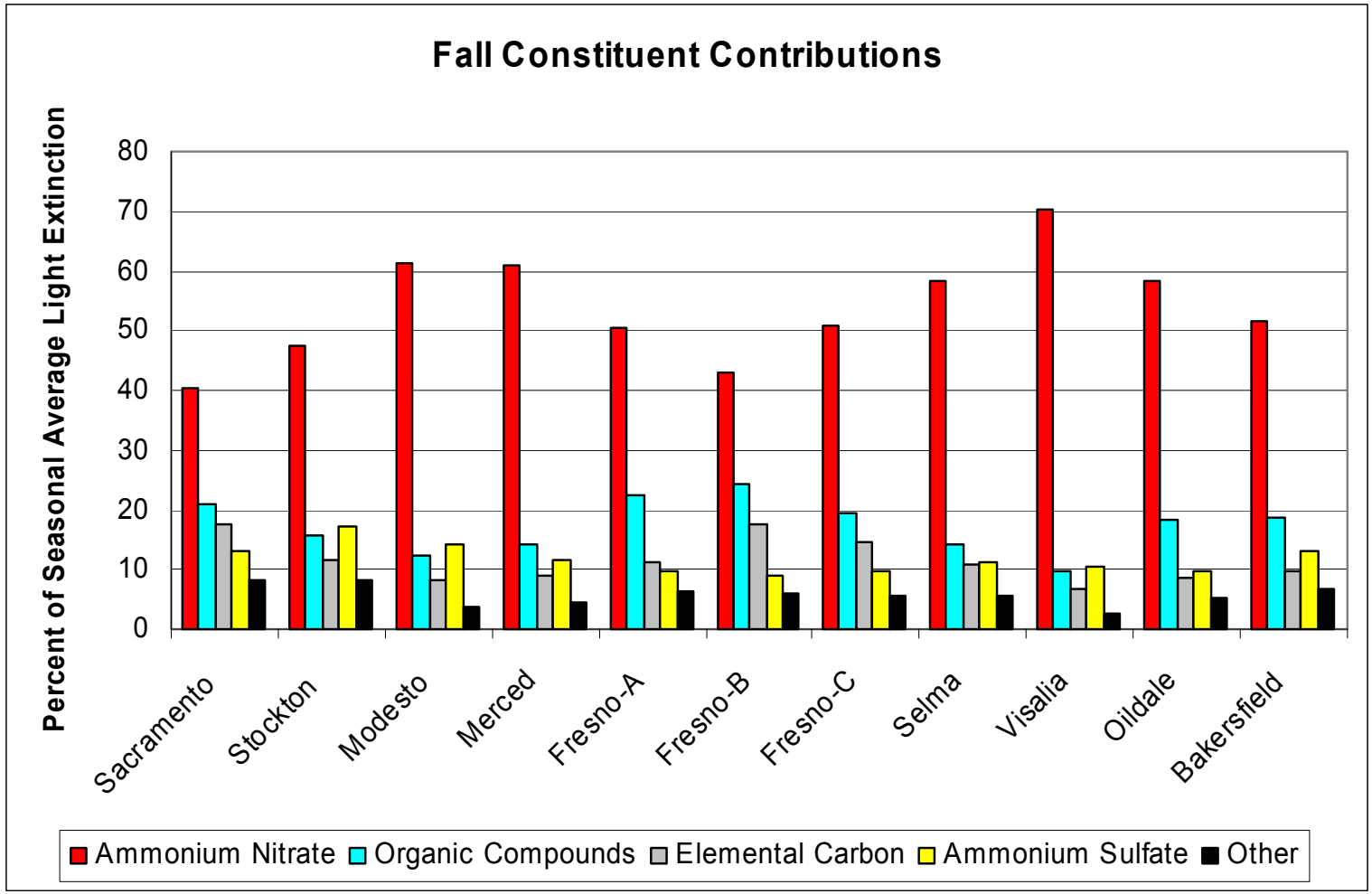

Sacramento
Stockton
San Francisco
Modesto
San Jose
Merced
Fresno (3)
Selma
Visalia
Oildale
Bakersfield

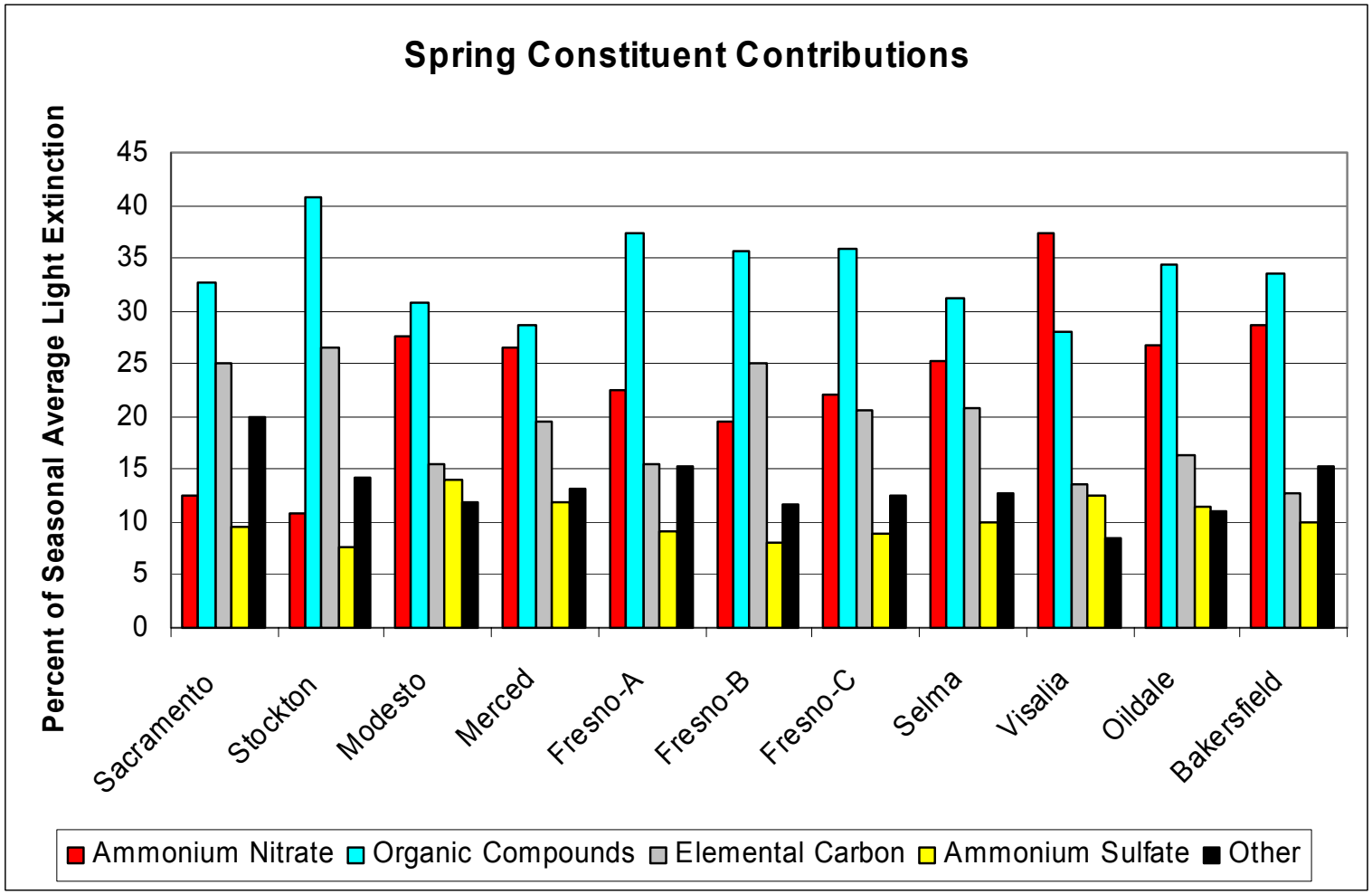

Seasonal Average Total Calculated Light Extinction
Seasonal Average Calculated Light Extinction (Mm -1)
900
800
700
600
500
400
300
200
100
0
Sacramento
Stockton
Modesto
Merced
Fresno-A
Fresno-B
Fresno-C
Selma
Visalia
Oildale
Bakersfield
Winter
Spring
Summer
Fall

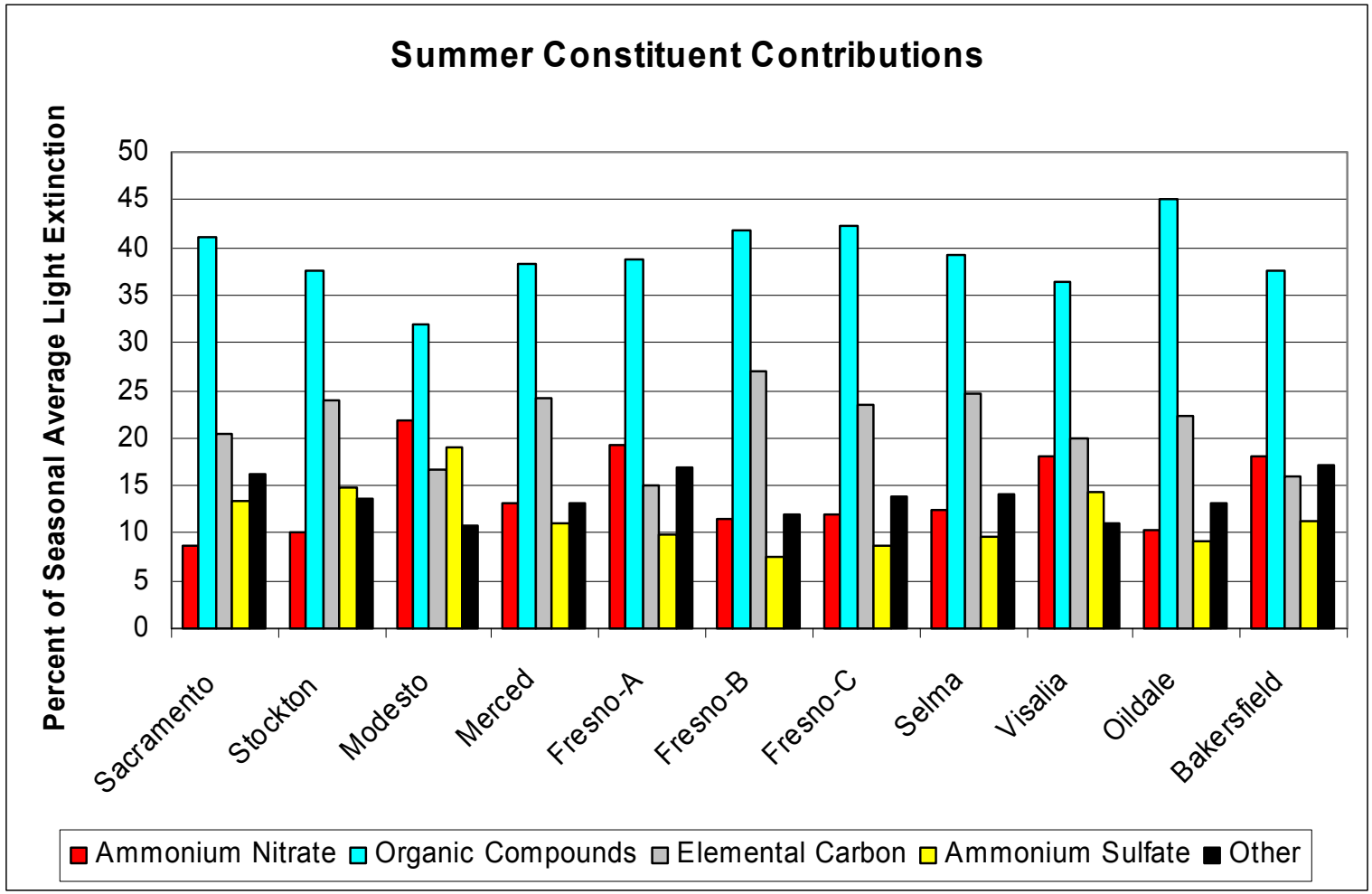
# Seasonal Average Total Calculated Light Extinction Coefficient

- Winter average values are higher than other seasons at all sites
- Fall average values are higher than spring or summer
- Values are highest at Visalia, Merced and Modesto
- Values are lowest at Sacramento and Stockton


Winter Constituent Contributions
Percent of Seasonal Average Light Extinction
90
80
70
60
50
40
30
20
10
0
Sacramento
Stockton
Modesto
Merced
Fresno-A
Fresno-B
Fresno-C
Selma
Visalia
Oildale
Bakersfield
Ammonium Nitrate
Organic Compounds
Elemental Carbon
Ammonium Sulfate
Other


Fall Constituent Contributions
Percent of Seasonal Average Light Extinction
80
70
60
50
40
30
20
10
0
Sacramento
Stockton
Modesto
Merced
Fresno-A
Fresno-B
Fresno-C
Selma
Visalia
Oildale
Bakersfield
Ammonium Nitrate
Organic Compounds
Elemental Carbon
Ammonium Sulfate
Other


Spring Constituent Contributions
Percent of Seasonal Average Light Extinction
45
40
35
30
25
20
15
10
5
0
Sacramento
Stockton
Modesto
Merced
Fresno-A
Fresno-B
Fresno-C
Selma
Visalia
Oildale
Bakersfield
Ammonium Nitrate
Organic Compounds
Elemental Carbon
Ammonium Sulfate
Other

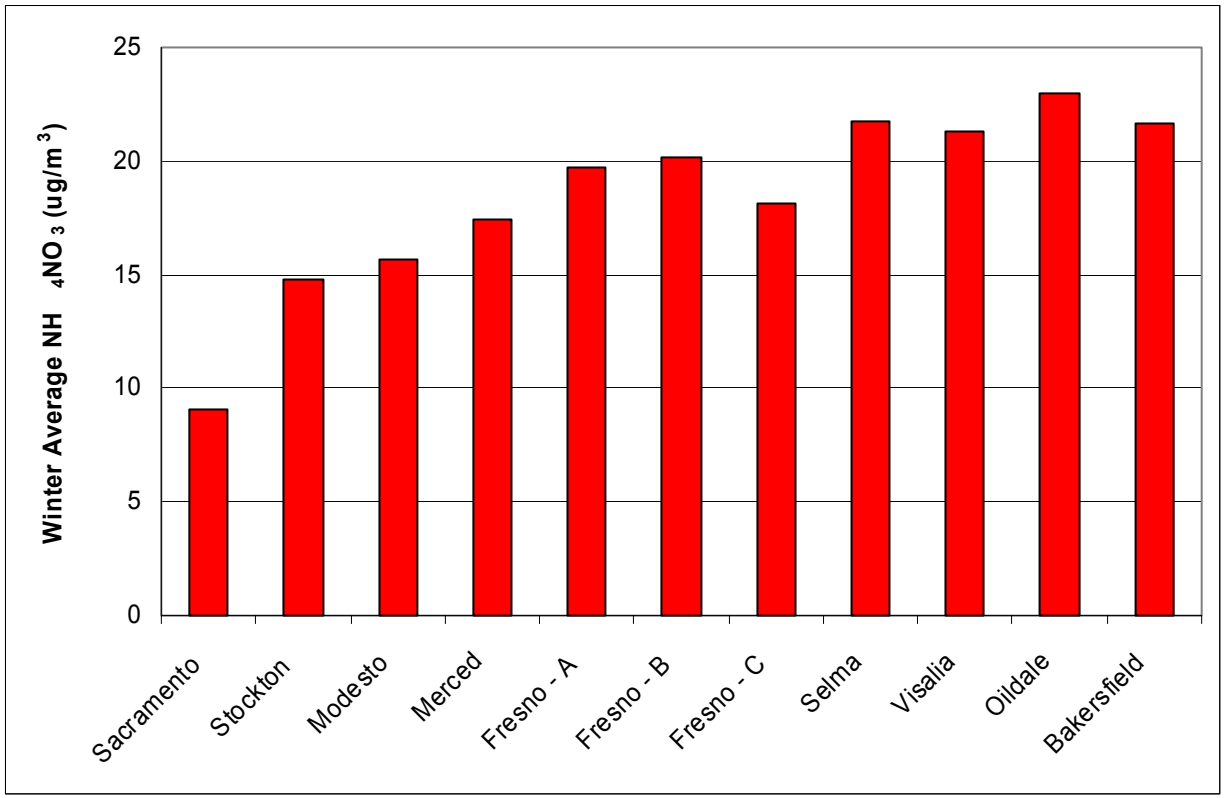

Summer Constituent Contributions
Percent of Seasonal Average Light Extinction
50
45
40
35
30
25
20
15
10
5
0
Sacramento
Stockton
Modesto
Merced
Fresno-A
Fresno-B
Fresno-C
Selma
Visalia
Oildale
Bakersfield
Ammonium Nitrate
Organic Compounds
Elemental Carbon
Ammonium Sulfate
Other

# Seasonal Average Constituent Contributions

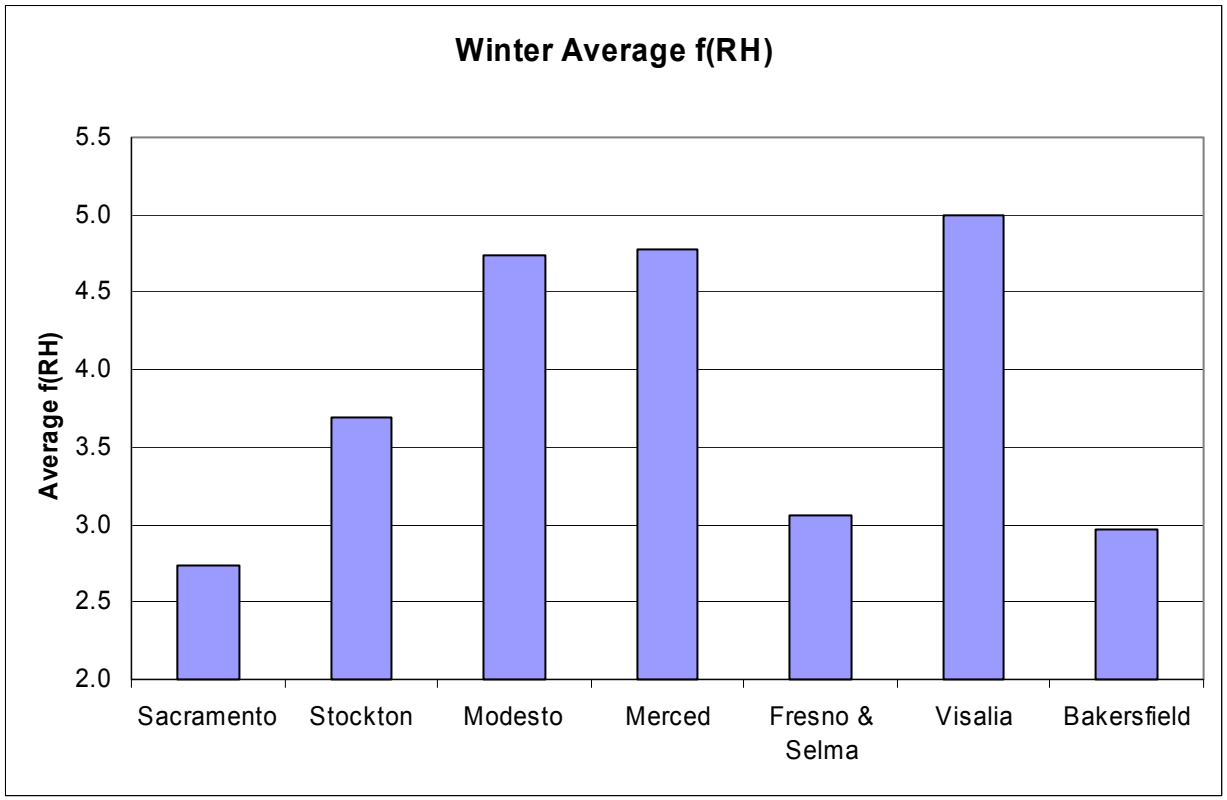
- $NH_4NO_3$ is largest contributor at all sites during winter and fall, accounting for about 60% to about 80% during winter and about 40% to about 70% during fall
- Organic compounds are largest contributor at most sites during spring, accounting for about 30% to about 40%, and at all sites during summer, accounting for about 30% to about 45%
- Elemental carbon is a significant contributor at most sites during spring and summer, accounting for as much as 25%

# Why is Winter Calculated Light Extinction Higher at Visalia, Merced and Modesto than at Other Sites?

# Winter Average $NH_4NO_3$ Concentrations are Higher at Other Sites



# But Average f(RH) is Lower at Other Sites



# Summary

- Previously developed light scattering efficiencies under-predicted measured light scattering, but seasonal adjustment factors improved agreement
- Calculated total light extinction is highest during winter and lowest during summer
- $NH_4NO_3$ is the largest contributor at all sites during winter and fall
- Organic compounds are the highest contributor at most sites during spring and summer
- Winter average light extinction was higher at Visalia, Merced and Modesto than at other sites because of higher reported relative humidity