# IMPROVE and Protocol Network

I.   History,

II.  Current Funding,

III. Process to Shape the Future

IV. Example Process Methods

By Marc Pitchford

May 5

# IMPROVE and Protocol Monitoring Network History

# Federal Visibility Protection & IMPROVE Monitoring

- 1977: Clean Air Act Amendments established the national goal to reduce existing and prevent future man-made visibility impairment in Federal Class I Areas (FCIA)
- 1980: EPA issues Phase I Visibility Rule that called for monitoring of FCIA visibility (among other things)
- 1984: Environmental Defense Fund sued EPA for not implementing rules in states without visibility SIPs
- 1985: EPA initiated IMPROVE to monitor FCIA visibility at 20 locations as part of the settlement agreement

# Federal Class I Areas (FCIA)
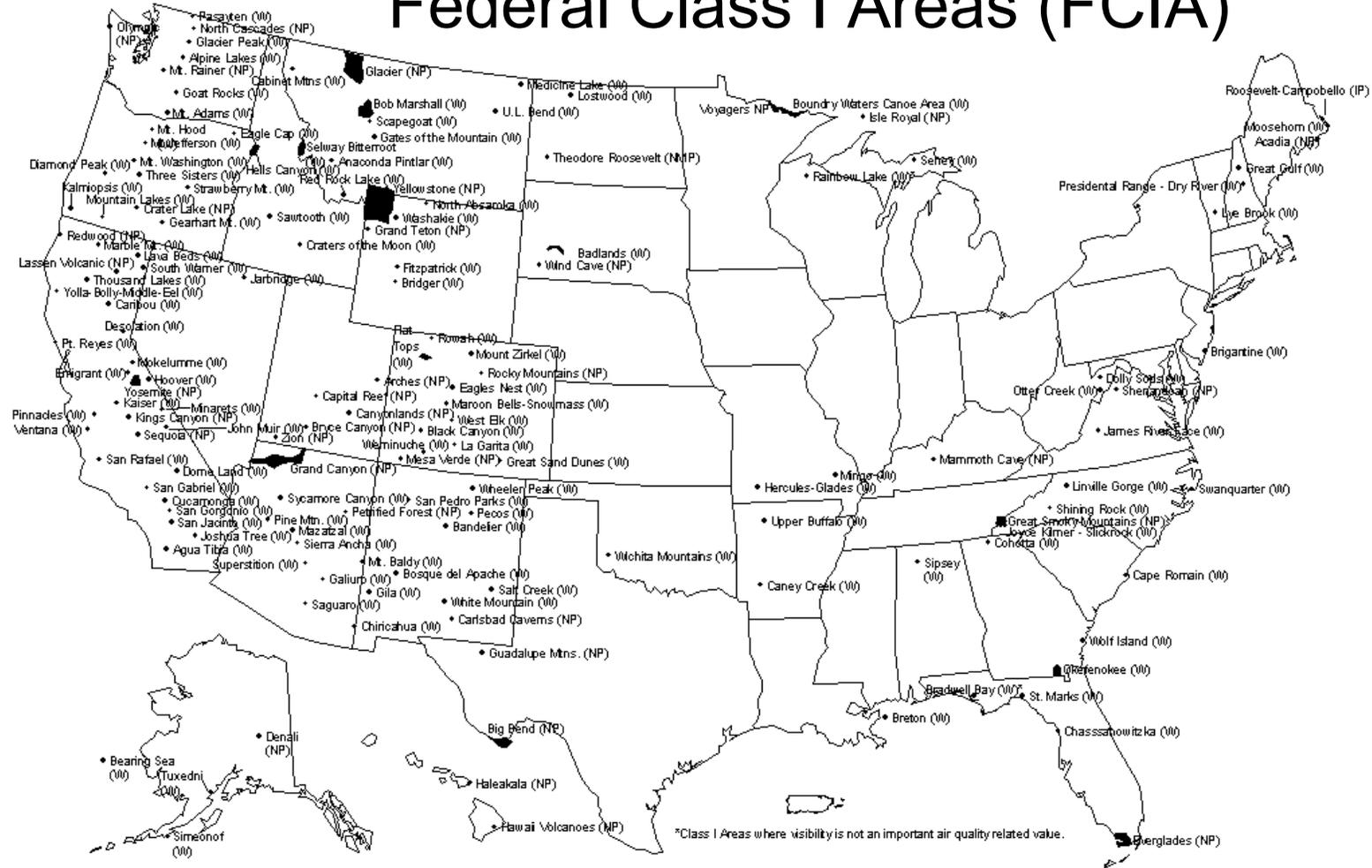


Map of 156 National Park and Wilderness Areas
Protected by EPA's Regional Haze Rule

Legend:
NP = National Park
W = Wilderness
IP = International Park

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# IMPROVE Objectives

- Establish current visibility and aerosol conditions in FCIA;

- Identify chemical species and emission sources responsible for existing man-made visibility impairment in FCIA; and

- Document long-term trends for assessing progress towards the national visibility goal for FCIA (& as required by the Regional Haze Rule)[1.]

1. Added in 1999

# IMPROVE Management

- Steering Committee with representatives from EPA, NPS, FWS, BLM, FS, STAPPA/ALAPCO, WESTAR, NESCAUM, MIRAMA, NOAA & AZ-DEQ

- NPS administers all contracts (aerosol, optical, data processing, etc.)

- EPA resources used to supply aerosol monitoring at each site plus associated QA, data processing, etc.

- Each land-management agency is responsible for providing field support (operators, power, security, etc.) and any optical &/or scene monitoring at their sites

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# IMPROVE Network History

- 20 site network started in 1987 contained aerosol monitoring at all sites & optical and scene monitoring at most

- 10 additional sites in 1991/92 with aerosol and some optical monitoring added to track expected Eastern sulfate changes

- Aerosol monitoring added to expand the network to 110 sites in support of the Regional Haze Rule - 1999 to 2001

# IMPROVE Network  1992-1999
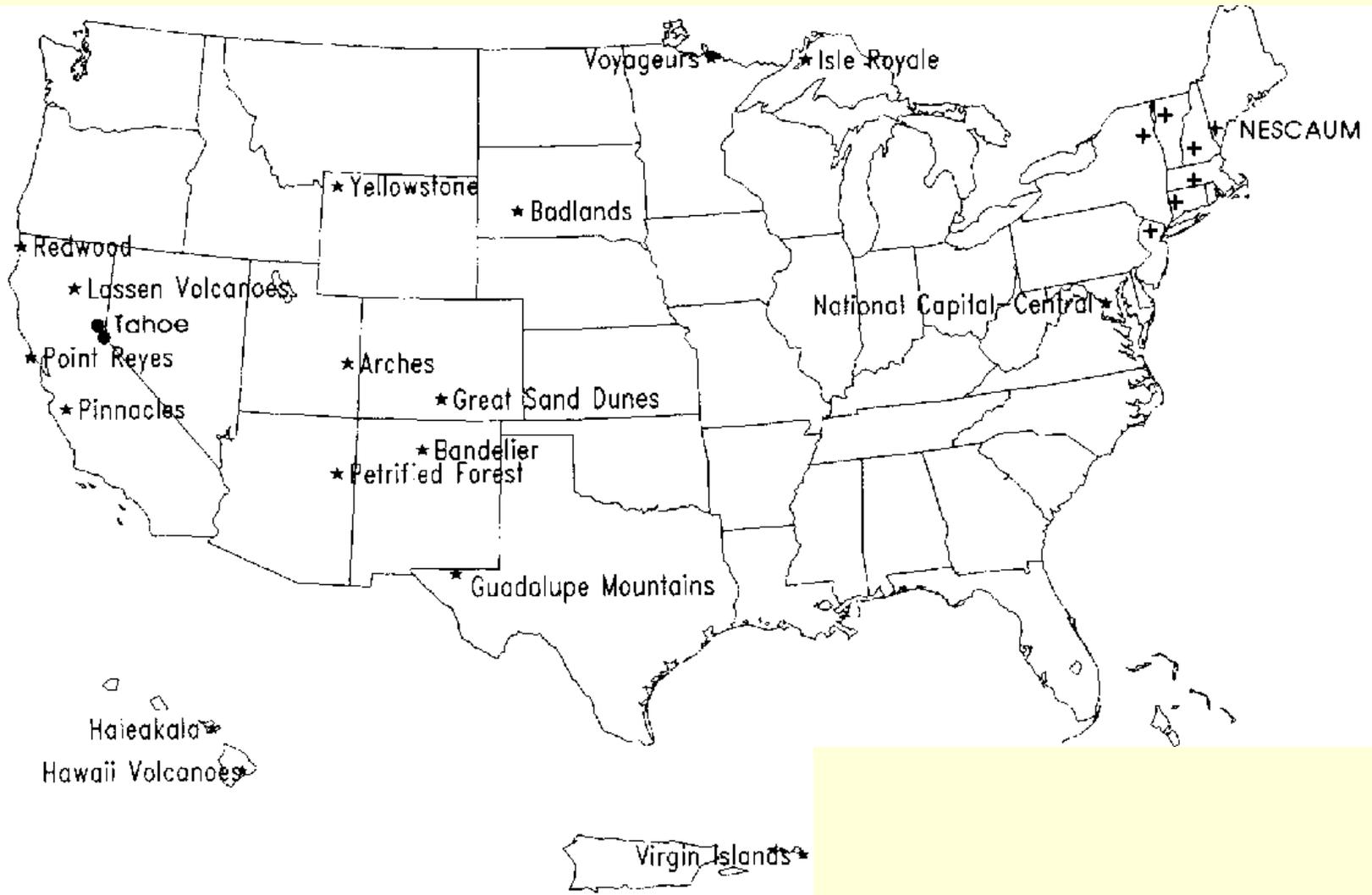
# IMPROVE Protocol Sites

- Same as IMPROVE with respect to
  - Equipment & supplies
  - Field & laboratory protocols & support contractors
  - Data processing & distribution
- Different from IMPROVE with respect to
  - Monitoring sites need not represent FCIA
  - EPA, NPS, & UCD need to agree to the sites
  - Steering Committee does not manage them

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# IMPROVE Protocol Sites in 1992

# Regional Haze Rule Monitoring Requirements

- Aerosol speciation monitoring patterned on the IMPROVE sampling/analysis protocol

- Representative of all 156 FCIAs, where possible

- Beginning in 2000, the 1$^{st}$ year of a five-year baseline

- Aerosol data converted to the deciview index used to track worst 20% and best 20% haze conditions

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# Regional Haze Representative Monitoring Considerations

- Wilderness Act forbids monitoring within most FCIA boundaries

- Regional haze is defined by EPA as being caused by multiple sources & activities, and having a broad geographic extent

- Remote area particle concentration and composition monitoring data show regional scale distributions

# Regional Haze FCIA Representative Monitoring

- A representative site should be influenced by the same regionally important sources that impact the FCIA

- It should be isolated as much as possible from solely local impacts

- Consequently regional haze monitoring can be done at a distance from a FCIA & may be able to represent multiple FCIAs in a region

# Regional Haze Network Expansion Design Objectives

- Minimize number of sites needed to represent all FCIAs

- Continue current IMPROVE sites

- Ensure input to all interested state and federal land management organizations (STAPPA forwarded the siting criteria and list of proposed sites to all state. Received comments from 17 states & incorporated all recommendations in final network design)

# IMPROVE & Protocol Sites -2001



● IMPROVE Sites (1-110)

○ Protocol Sites (111-143)

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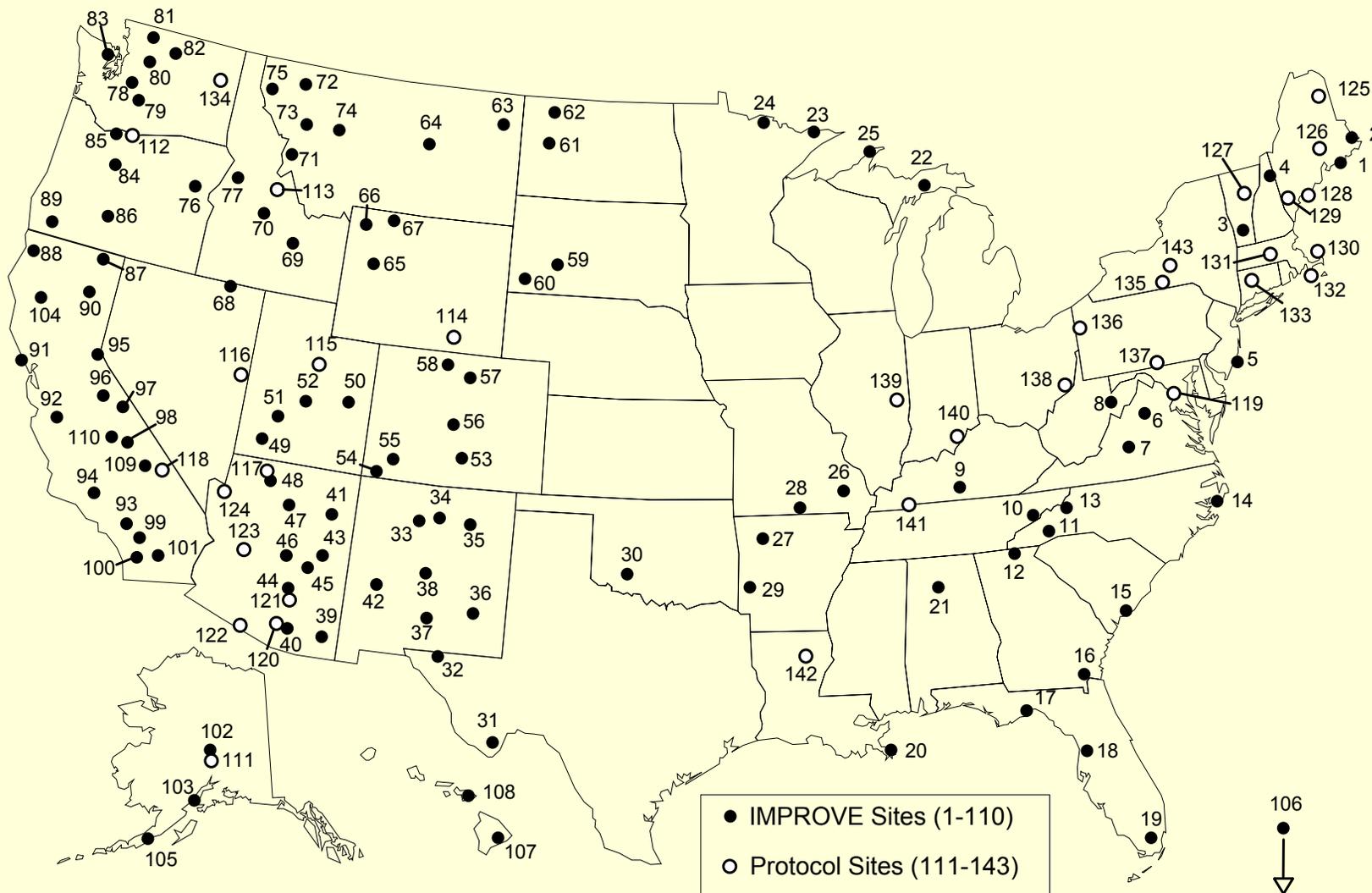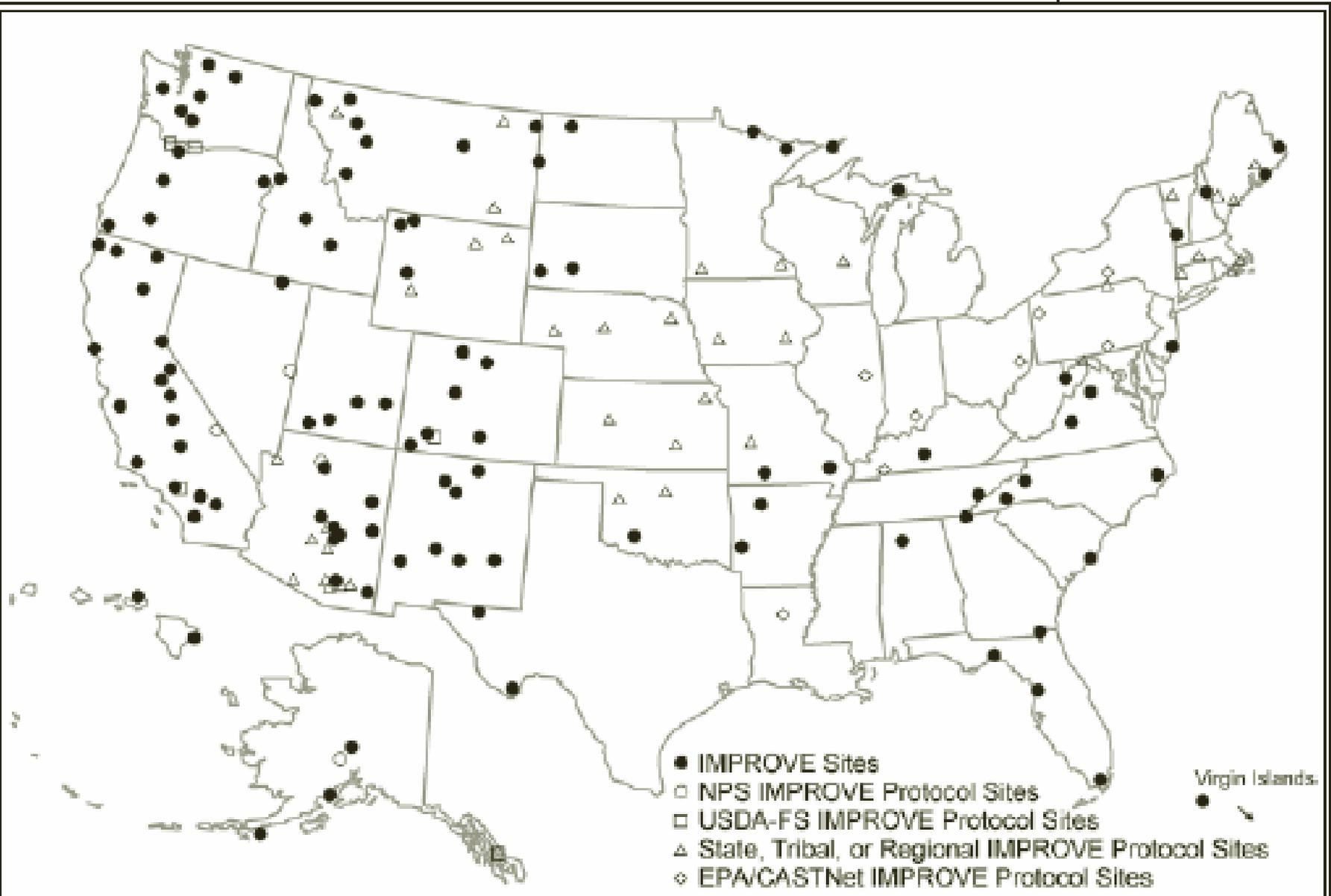
**IMPROVE and IMPROVE Protocol Sites**
**4th Quarter 2005**

Legend:
- ● IMPROVE Sites
- □ NPS IMPROVE Protocol Sites
- □ USDA-FS IMPROVE Protocol Sites
- △ State, Tribal, or Regional IMPROVE Protocol Sites
- ◇ EPA/CASTNet IMPROVE Protocol Sites

Virgin Islands

## IMPROVE and Protocol Monitoring Network 2006 Funding Estimates

| Type | # | Sect 103 | Sect 105 | FLM[1] | Total |
|---|---|---|---|---|---|
| IMPROVE | 110 | $2,340k | $1,232k | ~$800k | $4,371k |
| State | 28 | $966k | $0 | $0 | $966k |
| CASTNET[2] | 7 | $241k | $0 | $0 | $241k |
| Urban Collocated[2] | 5 | $172 | $0 | $0 | $172k |
| Tribal[2] | 9 | ? | ? | $0 | $315k |
| FLM | 9 | $0 | $0 | ~$382k | $382k |
| Total | 168 | $3,719k | $1,232k | $1,182k | $6,447k |

1. FLMs pay site operators at all IMPROVE sites, and both the operators and their sites' contractor costs for all FLM Protocol sites.

2. CASTNET, Urban Collocated, and Tribal costs don't include site operators' costs.

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# Budget Assessment

- IMPROVE network budget consists of
  - Site-specific cost ~$2,200/site/year
  - Sample-specific cost ~$13,300/site/year (~$9,800 is for sample composition analysis)
  - Network-wide cost ~$18,500/site/year for the current network (175 sites). For the purpose of this assessment these cost will be held constant. [Network-wide cost cover quality assurance, data processing, methods and procedures evaluation and refinement, communications, etc.]

**Summary/comparison of cost savings and cost per site are shown using three IMPROVE Network budget reduction approaches.**

| # Sites Affected | Site Reductions | | Gravimetric Screening[1] | Mothball | |
|---|---|---|---|---|---|
| | Savings | Cost/Site | Savings | Savings | Cost/site[2] |
| 0 | $0 | $34,000 | $0 | $0 | $34,000 |
| 5 | $77,600 | $34,544 | $24,500 | $15,500 | $34,106 |
| 10 | $155,200 | $35,120 | $49,000 | $31,000 | $34,214 |
| 15 | $232,800 | $35,733 | $73,500 | $46,500 | $34,323 |
| 20 | $310,400 | $36,385 | $98,000 | $62,000 | $34,433 |
| 25 | $388,000 | $37,080 | $122,500 | $77,500 | $34,544 |
| 30 | $465,600 | $37,823 | $147,000 | $93,000 | $34,657 |
| 35 | $543,200 | $38,620 | $171,500 | $108,500 | $34,771 |
| 40 | $620,800 | $39,476 | $196,000 | $124,000 | $34,886 |
| 100 | | | $490,000 | $310,000 | $36,387 |
| 150 | | | $735,000 | $465,000 | $37,828 |

[1] Cost/site for sites employing Gravimetric Screening is ~$29,100, other sites are ~$34,000

[2] Cost/site shown for sites employing the Mothball approach is for the four years that they operate, every fifth year their cost are $0/site

# Proposed Process for Rating IMPROVE and Protocol Sites

- ## Process Purpose
  - Anticipated FY2007 EPA budget cuts will reduce the funds available for the IMPROVE and Protocol monitoring programs
  - Some of the ~170 monitoring sites will likely be discontinued to cope with any funding cuts
  - Multiple organizations have a stake in the continuation of these sites
  - Consequences of potential funding changes need to be known prior to making final decisions

# Proposed Process for Rating IMPROVE and Protocol Sites

- • Process Approach
  - – Invite participation of all organizations with a stake in the monitoring (states, FLMs, RPOs, tribes, EPA, etc.)
  - – Gather and organize pertinent technical, regulatory and programmatic site-specific information
  - – Develop and implement methods to assess the consequences associated with discontinuing each individual site
  - – Organize sites into groups based on judged importance (e.g. legally required, critical, important, etc.)
  - – Marc Pitchford is willing to lead this assessment but will need assistance from others

# Preliminary breakdown of IMPROVE/Protocol network sites by sponsor and primary purpose

| Category | Type | Sponsor | Primary Purpose | Number |
|---|---|---|---|---|
| IMPROVE | RHR Compliant | EPA | Represent 155 class I areas for the Regional Haze Rule trends tracking | 110 |
| IMPROVE Protocol | RHR Supplemental | States via EPA-grants | Supplement the IMPROVE sites in representing class I areas | ~7 |
| | Geo-Gap Fillers | States/RPOs via EPA-grants | Fill geographic gaps to monitor PM & haze regional patterns | ~20 |
| | Background & transport | States via EPA-grants | Some state use Protocol sites for PM background and transport monitoring | ~8 |
| | Local Issues | State/Tribes via EPA-grants | Assess local PM air quality with a regional context | ~7 |
| | Special Studies | EPA & others | Short-term (6 to 24 months) support of special studies | ~2 |
| | Urban | EPA | Assess comparability between STN and IMPROVE | ~4 |
| | Land-Manager Support | FLM | Service FLM needs for PM speciation data in non-class I areas | 9 |

• Cuts will affect budgets of yellow and blue shaded sites and perhaps some unshaded site, but red sites are not EPA funded.

• Approximate numbers show uncertainty in the primary purpose of some protocol sites, plus some changes to status for special studies.

• Additional site-specific information needs to be gathered and organized.

# Joint Benefits and Utility of the IMPROVE/Protocol Network

- Uniform methodology applied nationwide for over 18 years with multiple sponsors
  - Cost-effective sampling/analyses due to volume procurement and cost-sharing with FLMs (at all 110 sites plus some others)
  - NPS contract management and negotiated low contract overhead rates (e.g. <28% for UCD)
  - Site-to-site and temporal data comparability are optimized

- Applications
  - National, regional, & local trends analyses
  - Identification of episodes of long-range transport (e.g. smoke, dust, sulfates, nitrates, etc from distant sources)
  - Regional backdrop for special studies
  - Regional modeling validation data set
  - Supports the development and implementation of $PM_{2.5}$ & $PM_{coarse}$ NAAQS by characterizing the non-urban regional background levels

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# Proposed Approach for Organizing Pertinent Site-Specific Information

- Prepare a site information spreadsheet
  - Each site is a row
  - Columns for: name, location (lat., long., elevation, state), years of operation, sponsor, primary purpose, other purposes, collocated equipment, data recovery last year, other comments
- Solicit input from sponsors and other organizations to populate the spreadsheet

# Methods to Assess Consequences of Discontinuing Any Site

- Develop distinct methods to assess the relative importance of each site in meeting its primary purpose (e.g. representing class I areas, filling geographic gaps, etc.)

- Identify the point where further site reductions fail to meet the primary purpose, if possible.

- Document the technical, regulatory and programmatic consequences of
  - reduced ability to meet the various primary purposes
  - Failure to meet the various primary purposes

# Examples Elements of the Proposed Process

- Site Information Spreadsheet
- Method to estimate the relative importance of each site to generating spatial patterns
- Method to assess how to reassign class I area monitoring to fewer IMPROVE sites
- Thoughts on additional methods to assess the importance of other sites

# Site Information Spreadsheet

- **Information available** (in several spreadsheets)
  - Name, site code, state, map coordinates, elevation, start date, type, sponsor, last year's data recovery, class I areas represented (IMPROVE)

- **Information needed**
  - Principal purpose (protocol), other purposes, collocated equipment, candidate alternate site that would meet the primary purpose, other comments

# Approach for Identifying Data Redundancy and Regions of Over-Monitoring

- Predict concentrations of each sites' major components using distance weighted (1/r) spatial interpolation (2003 & 2004)

- Calculate the fractional error between predicted and observed

$$FE \equiv \frac{2}{n} \sum_{i=1}^{n} \frac{|p_i - o_i|}{(p_i - o_i)}$$

  - Low fractional error → redundant data
  - High fractional error → unique data
- Map fractional errors to show spatial patterns

# Component Fractional Error Contour Maps

Sulfate fractional error map

- Low fractional errors (FE<0.4) over most of the country

- Many sites are redundant if sulfate is the only concern
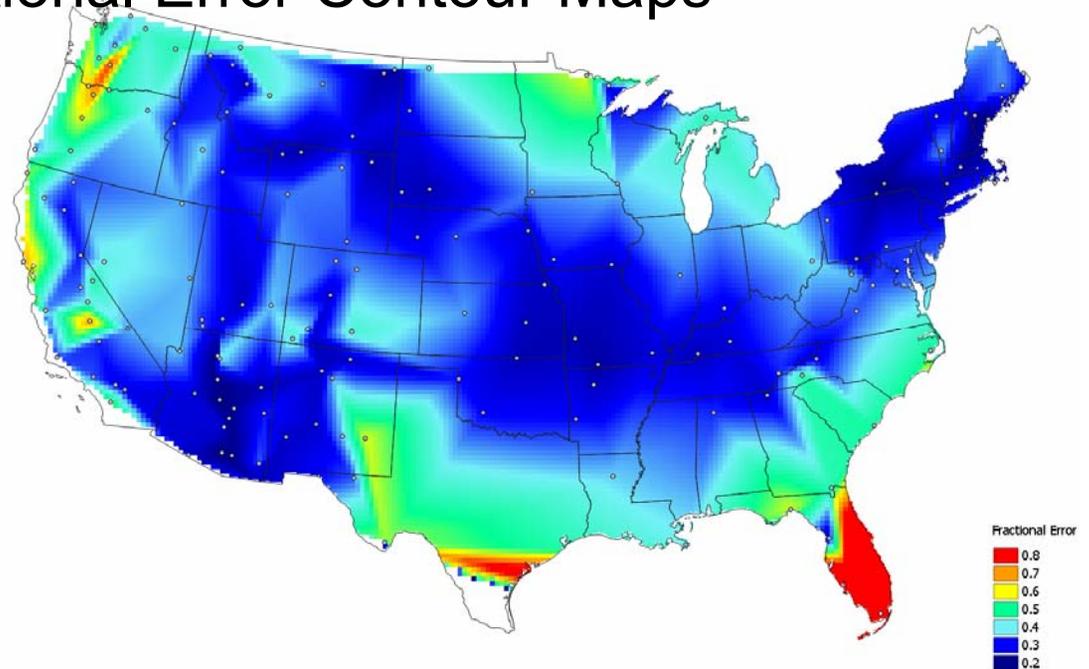
Nitrate fractional error map

- Low fractional errors (FE<0.4) in several small regions and in the center of the country

- Most regions have sites that are more unique with respect to nitrates
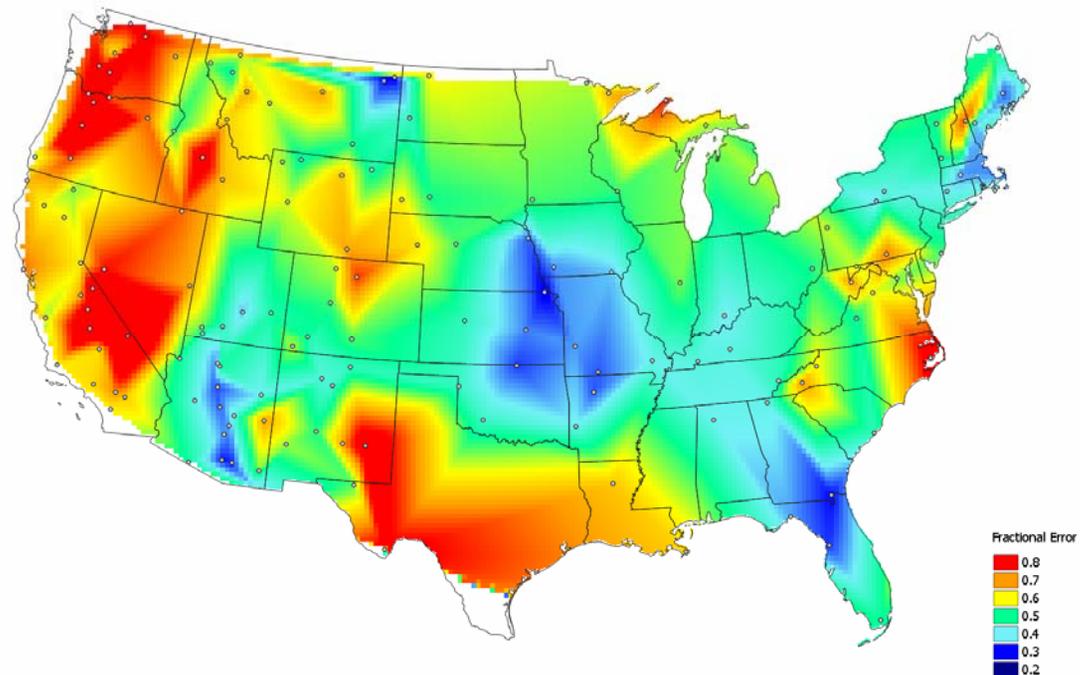
# Component Fractional Error Contour Maps

**Organic fractional error map**

- Low fractional errors (FE<0.4) over much of the center and eastern U.S. and in southern AZ

- Some regions in the west are highly unique (smoke impact areas?), while other regions are less unique (secondary biogenic impacts?)
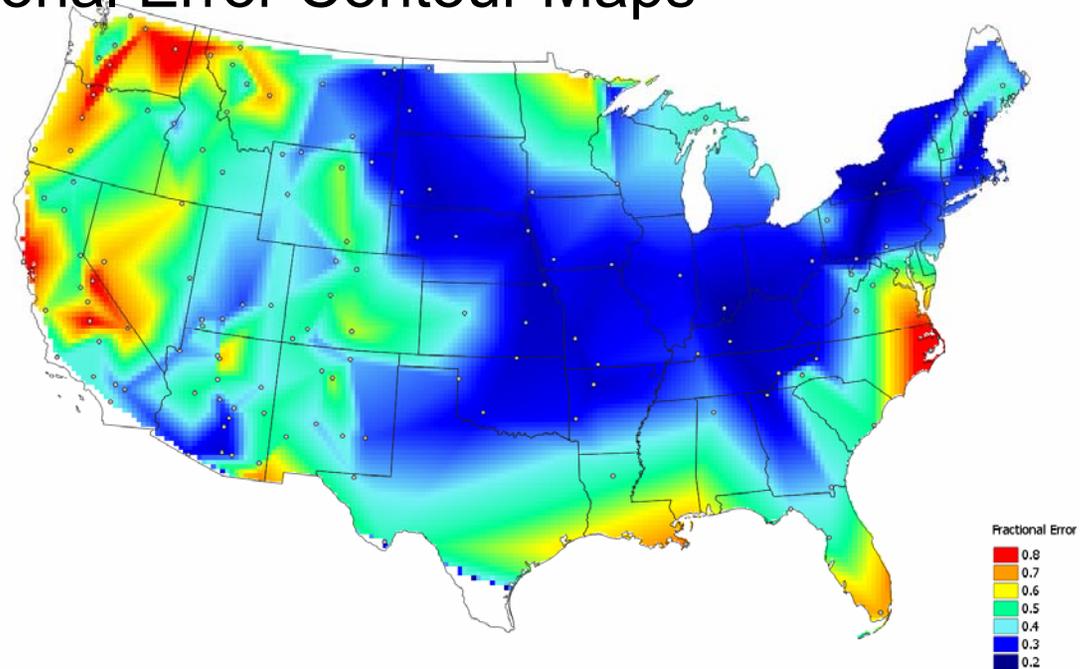


**Elemental Carbon fractional error map**

- Low fractional errors (FE<0.4) over much of the center and eastern U.S.

- Compared to the organic map, the west has larger regions of uniqueness (maybe because there is no secondary elemental carbon)
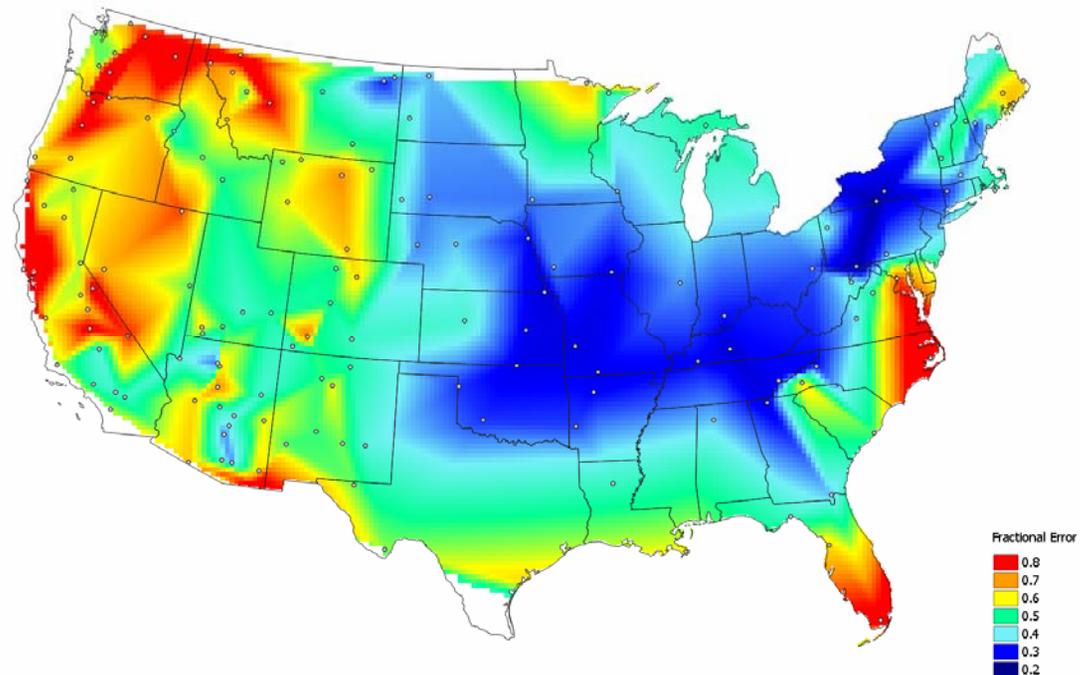
# Component Fractional Error Contour Maps

Fine Soil fractional error map

- Low fractional errors (FE<0.4) over the center of the country and a few small regions
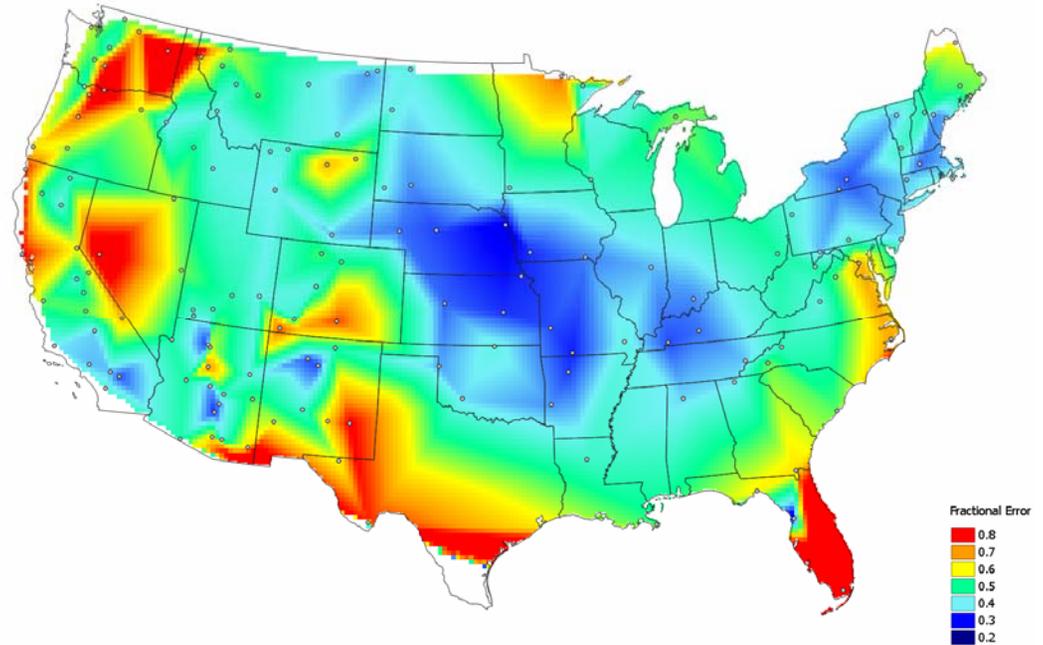


Coarse Mass fractional error map

- Low fractional errors (FE<0.4) in a few small regions in the center of the country and northeast

- As would be expected with coarse mass, many of the site's data are unique
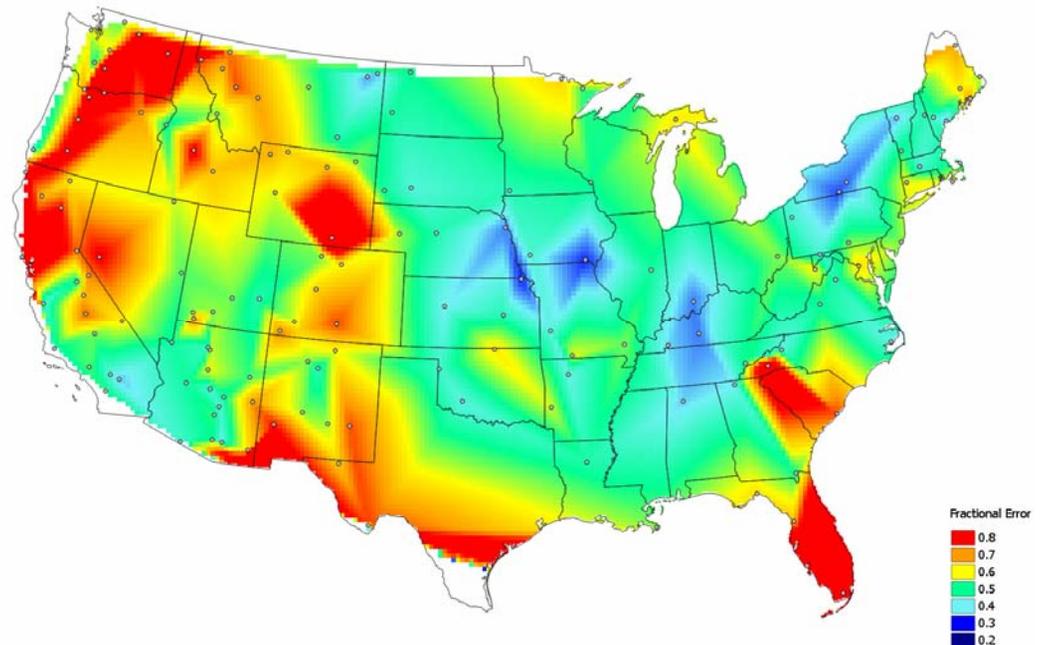
# Composite Parameter Fractional Error Contour Maps

Site-maximum component fractional error map

- This map treats each component equally by displaying the components largest fractional error

- Shows the center of the country, regions in the northeast, AZ and MT as having redundant sites
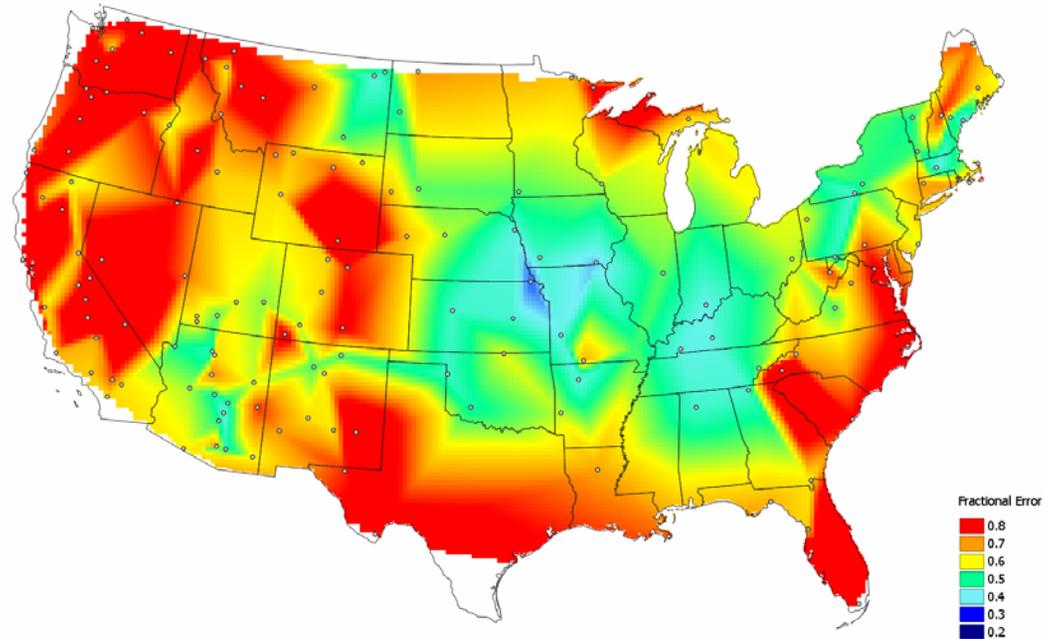
Aerosol extinction fractional error map (note the different scale)

- This map weights the components by their contribution to light extinction

- Because haze is dominated in the east by sulfate, which is the most spatially uniform component, more of the eastern sites are redundant

- Also show parts of AZ & MT as having redundant sites
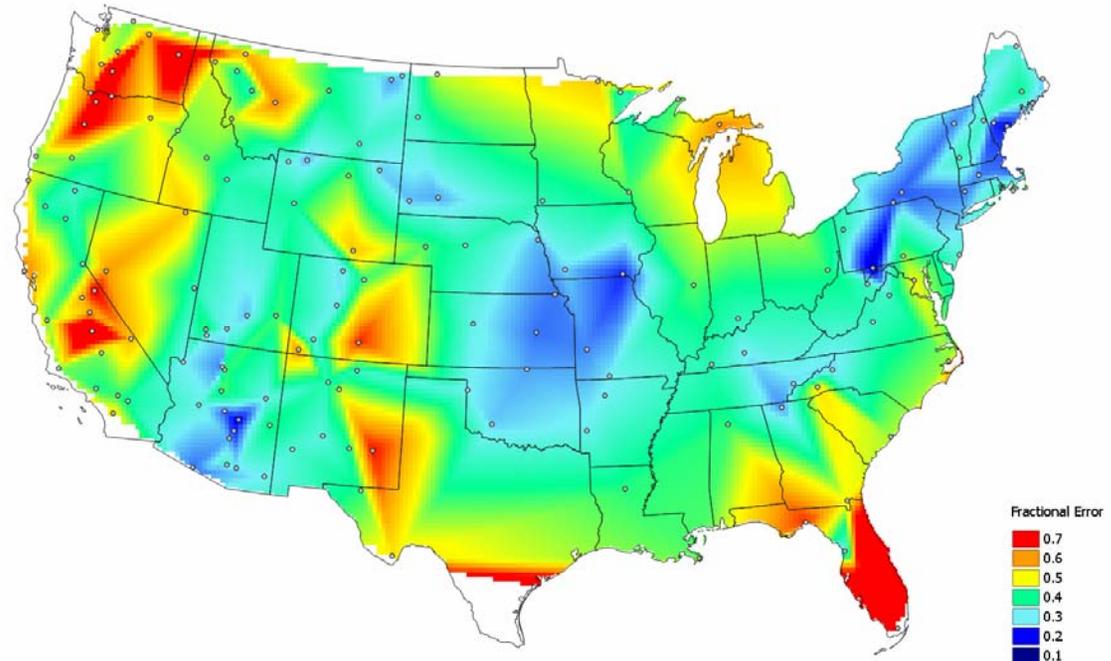
# Approach to priority listing of redundant sites

- Select the site with the lowest fractional error
- Remove its data and recalculate fractional errors for neighboring sites
- Select the new lowest fractional error non-protected site
- Remove its data and recalculate fraction errors for neighboring sites
- Repeat for as many non-protected sites as often as desired

# Example Application to Entire Network – In Practice Some Sites Would be Protected



**Rank**

- 🟥 1-10
- 🟨 11-20
- 🟩 21-30
- 🟦 31-40
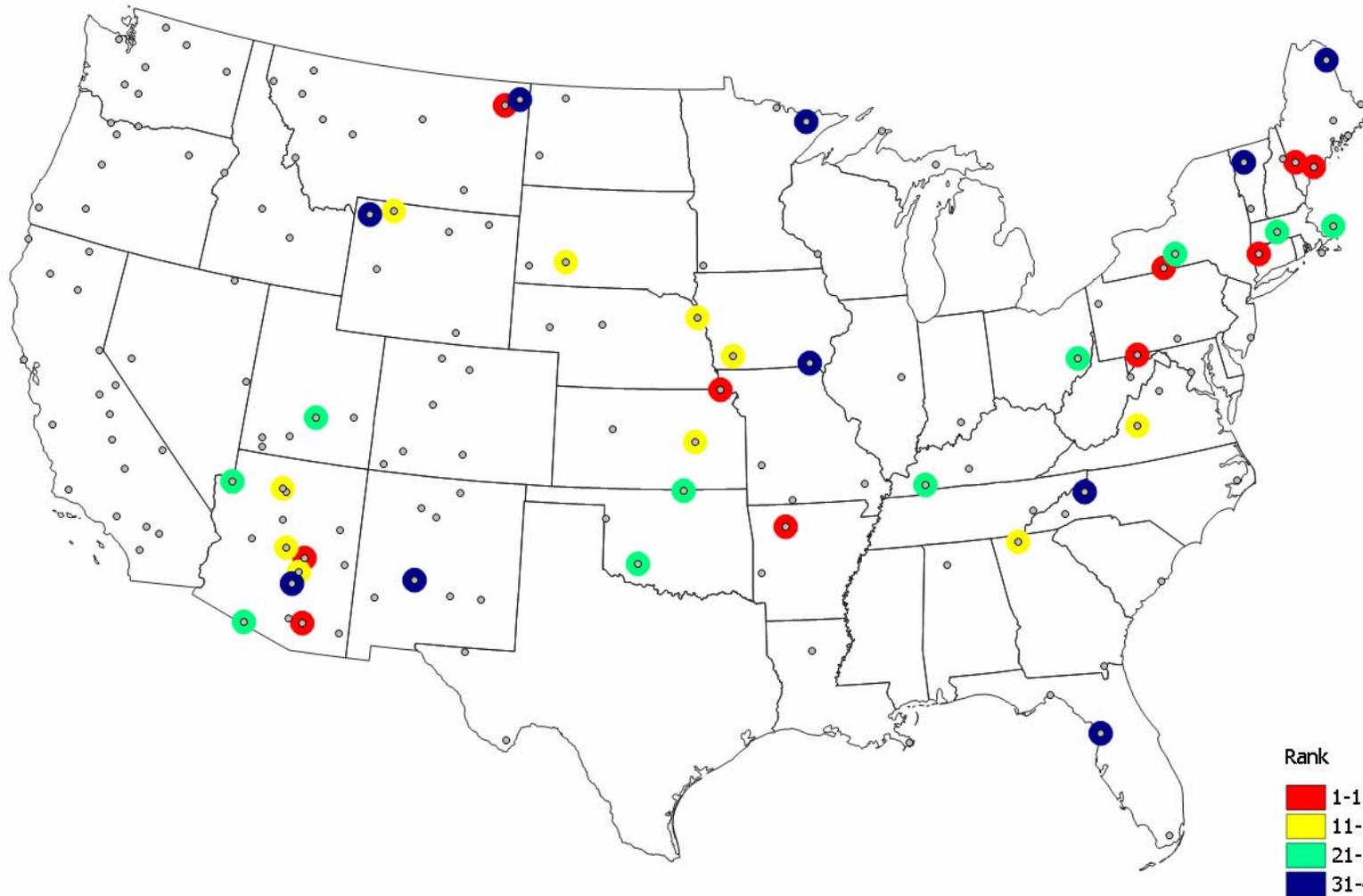
**Map shows the locations of the 40 most redundant sites selected using aerosol light extinction with fraction error recalculation after removal of data for each site selected and no protection by consideration of other factors.  Also shown are the locations of all IMPROVE/Protocol sites.**

# Regional Haze Rule Requirements for Monitoring

- Regional Haze Rule requires each of the 155 visibility class I areas have representative monitoring

- Original process(1998 & 1999) used two criteria and professional judgment to select the 110 IMPROVE sites

  - Sites should be within 100km of class I area

  - Site elevation should be within the class I area elevation range $\pm$100ft. or 10%

  - State air agencies and FLMs asked to apply local air quality knowledge and verify that the sites represent the class I areas

# Example Approach for Reducing the Numbers of IMPROVE Monitoring Sites

- Identify all class I areas that could be reassigned to another monitoring site within various distances (e.g. 100km, 200km and 300km)

- Develop alternate reconfigured class I area monitoring networks using each of these distance criteria with all class I area assigned to a monitoring site

- Document changes to the distance and elevation criteria (tables and maps) associated with each of the new configurations

- Seek comments from each state air agency and FLM concerning the adequacy of representative monitoring for their areas using the three distances criteria

- Some regions have more uniform haze conditions than other regions so the final configuration will likely be a composite of the results from the different distances

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Example method for the IMPROVE 110 sites

100km Radius Circles Centered on Each Class I Area in 48 States
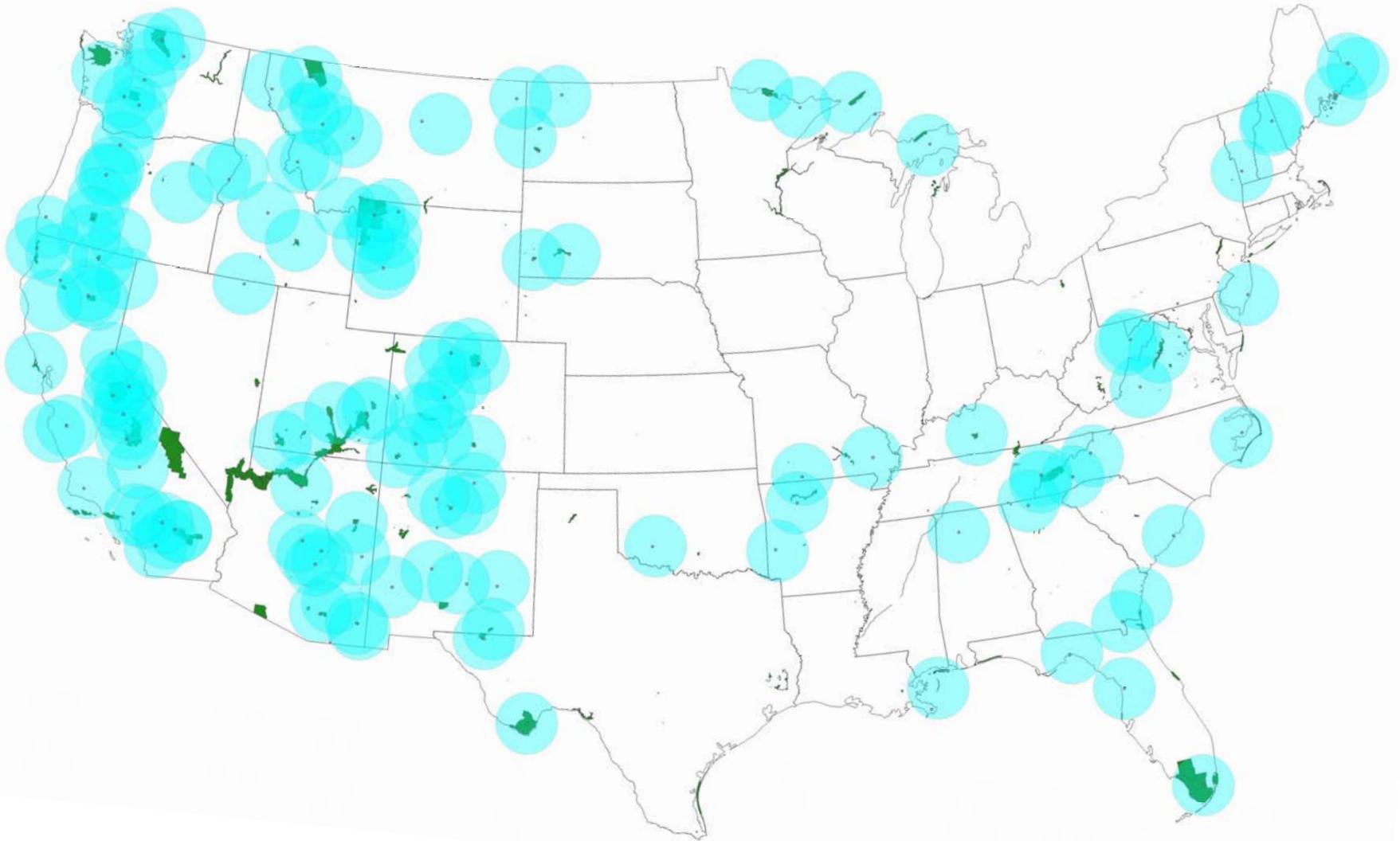
Example method for the IMPROVE 110 sites

100km Radius Circles Centered on Class I Areas in Alaska
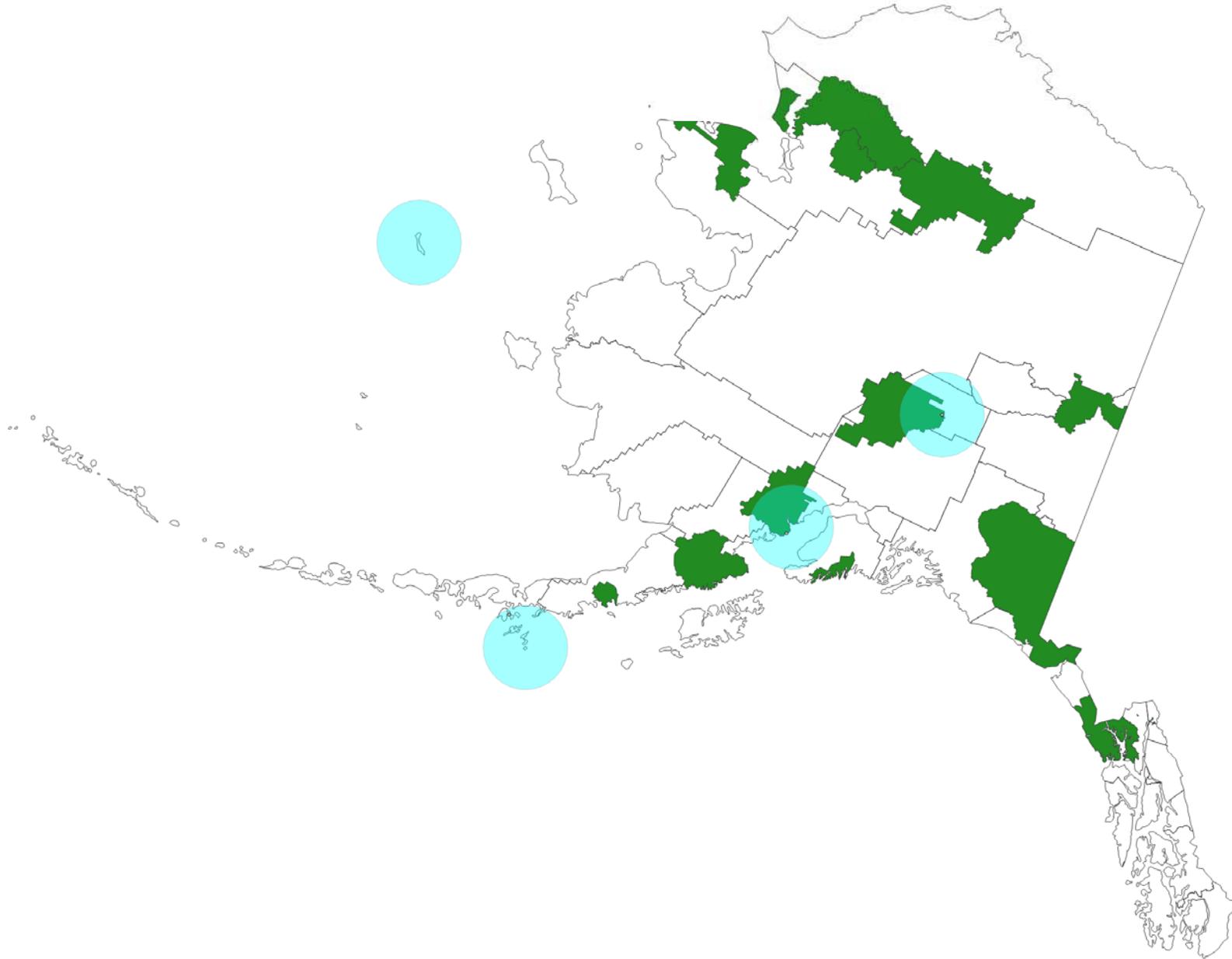
# Example method for the IMPROVE 110 sites

Example use of distance from class I areas (rows) to monitoring sites (columns) to identify monitoring sites that might be decommissioned

If distance to 200km is allowed, four class I areas could be represented by one monitoring site (James River Face, Shenandoah or Dolly Sods) permitting two sites to be removed

**Color key**

| |
|---|
| 0km to 50km |
| 50km to 100km |
| 100km to 150km |
| 150km to 200km |
| 200km to 250km |
| 250km to 300km |
| >300km |

| Group A | Virgin Islands | Cape Romain | Swan quarter | Linville Gorge | James River Face | Shenan doah | Dolly Sods | Briga ntine | Lye Brook | Great Gulf | Acadia | Moose horn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Virgin Islands | 0 | 2,204 | 2,215 | 2,589 | 2,583 | 2,608 | 2,711 | 2,532 | 2,876 | 2,960 | 2,930 | 3,006 |
| Cape Romain | 2,203 | 0 | 423 | 397 | 521 | 630 | 685 | 862 | 1,269 | 1,459 | 1,609 | 1,724 |
| Swanquarter | 2,205 | 408 | 17 | 518 | 387 | 405 | 506 | 489 | 911 | 1,088 | 1,218 | 1,332 |
| James River Face | 2,580 | 520 | 379 | 286 | 3 | 137 | 166 | 484 | 817 | 1,017 | 1,205 | 1,318 |
| Shenandoah | 2,608 | 630 | 394 | 421 | 137 | 0 | 108 | 361 | 681 | 881 | 1,070 | 1,182 |
| Otter Creek | 2,712 | 673 | 499 | 393 | 153 | 118 | 23 | 452 | 716 | 916 | 1,120 | 1,229 |
| Dolly Sods | 2,710 | 685 | 496 | 413 | 165 | 108 | 0 | 431 | 694 | 894 | 1,097 | 1,207 |
| Brigantine | 2,532 | 862 | 472 | 766 | 486 | 361 | 431 | 0 | 424 | 601 | 749 | 864 |
| Lye Brook | 2,875 | 1,269 | 894 | 1,099 | 818 | 681 | 694 | 423 | 0 | 201 | 415 | 518 |
| Pres. Range-Dry River | 2,952 | 1,444 | 1,057 | 1,284 | 1,003 | 866 | 879 | 586 | 186 | 15 | 248 | 340 |
| Great Gulf | 2,960 | 1,459 | 1,071 | 1,299 | 1,018 | 881 | 894 | 601 | 201 | 0 | 236 | 327 |
| Acadia | 2,929 | 1,608 | 1,201 | 1,490 | 1,206 | 1,069 | 1,097 | 749 | 415 | 236 | 0 | 115 |
| Roosevelt Campobello | 2,977 | 1,721 | 1,310 | 1,608 | 1,324 | 1,188 | 1,216 | 864 | 532 | 346 | 119 | 37 |
| Moosehorn | 3,005 | 1,723 | 1,315 | 1,602 | 1,319 | 1,181 | 1,206 | 864 | 518 | 327 | 115 | 1 |

Group A class I areas are east of -80 degrees longitude.  Larger font used for currently representative sites.

# Assess the Regulatory Consequences of Reducing the IMPROVE Network

- Regional Haze Rule requires each class I area to have representative monitoring
  - State are responsible conducting representative monitoring as documented in their RHR SIPs
  - EPA must approve each SIP, or issue a FIP
  - FLMs are responsible for protecting air resources including visibility of class I areas under the Clean Air Act
  - NGO's can challenge the adequacy of RHR SIP monitoring plans in court

# Alternative Approaches to Reduce IMPROVE Network Cost

- Only perform chemical analyses on samples that are likely to be among the 20% best & worst haze periods
  - Gravimetric fine and coarse mass to identify the 25% most likely to include the best 20% haze samples, and the same for worst haze periods (i.e. gravimetric screening approach)
  - Based on historic data at 7 sites
    - Almost 90% of correct days are selected
    - Fractional error in the annual mean of the best and worst haze days is about 2%
  - Disadvantages include
    - Compositional analyses will be delayed until after the year is completed
    - Composition data unavailable for the central 50% of the time, prevents or complicate many uses of the data

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# Alternative Approaches to Reduce IMPROVE Network Cost

- Sample only 4 years out of every 5 year-Regional Haze Regulation trend period
  - Each year mothball a different 20% of the sites selected to maintain geographic coverage
  - Disadvantages include
    - Disruption of trends, episode, source-attribution, etc. analyses for all participating sites
    - Unlike the gravimetric-screening approach, there are no after-the-fact opportunities to fill in missing data.

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# Summary/Conclusions/Recommendations

- Each IMPROVE and Protocol sites serve a number of purposes and the consequences of change need to be understood prior to proposing network downsizing or other changes
- A multi-participatory, transparent process to gather information, develop/apply assessment methods, propose and approve changes needs to be conducted
- Marc Pitchford can lead this endeavor, but requires the assistance of all of the stakeholders including STAPPA, IMPROVE, RPOs states, tribes, EPA, etc.

# Proposed Next Steps – Completion Dates

- Identify groups that want to be involved – May 2006
- Collect, organize and disseminate site-specific information – June 2006
- Develop methods to assess all IMPROVE and Protocol sites for their importance in meeting the primary purposes they serve – August 2006
- Assess consequence of changes – August 2006
- Propose a reduced network consistent with available funds – Fall 2006 (whenever FY07 budget is final)

# Additional Class I Areas
# Site Distance Tables

Groups are defined by Longitude and Latitude

Sites are initially chosen to be in areas with 5 degree buffers around the regions with the class I areas, then trimmed to remove sites where all distances exceed 300km

| | <-----------Site------------> | | | | <--------------Area-----------> | | | |
| Group | min long | max long | min lat | max lat | min long | max long | min lat | max lat |
|---|---|---|---|---|---|---|---|---|
| A | 55 | 85 | 10 | 55 | 60 | 80 | 15 | 50 |
| B | 75 | 105 | 10 | 55 | 80 | 100 | 15 | 50 |
| C | 95 | 115 | 10 | 45 | 100 | 110 | 15 | 40 |
| D | 95 | 115 | 35 | 55 | 100 | 110 | 40 | 50 |
| E | 105 | 125 | 10 | 45 | 110 | 120 | 15 | 40 |
| F | 105 | 125 | 35 | 55 | 110 | 120 | 40 | 50 |
| G | 115 | 145 | 10 | 55 | 120 | 140 | 15 | 50 |
| H | 135 | 165 | 10 | 70 | 140 | 160 | 15 | 65 |

Class I Area Groups A through H – Refers to Distance Tables

**Group A**

| | Virgin Islands | Cape Romain | Swan quarter | Linville Gorge | James River Face | Shenan doah | Dolly Sods | Briga ntine | Lye Brook | Great Gulf | Acadia | Moose horn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Virgin Islands | 0 | 2,204 | 2,215 | 2,589 | 2,583 | 2,608 | 2,711 | 2,532 | 2,876 | 2,960 | 2,930 | 3,006 |
| Cape Romain | 2,203 | 0 | 423 | 397 | 521 | 630 | 685 | 862 | 1,269 | 1,459 | 1,609 | 1,724 |
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| Lye Brook | 2,875 | 1,269 | 894 | 1,099 | 818 | 681 | 694 | 423 | 0 | 201 | 415 | 518 |
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| Acadia | 2,929 | 1,608 | 1,201 | 1,490 | 1,206 | 1,069 | 1,097 | 749 | 415 | 236 | 0 | 115 |
| Roosevelt Campobello | 2,977 | 1,721 | 1,310 | 1,608 | 1,324 | 1,188 | 1,216 | 864 | 532 | 346 | 119 | 37 |
| Moosehorn | 3,005 | 1,723 | 1,315 | 1,602 | 1,319 | 1,181 | 1,206 | 864 | 518 | 327 | 115 | 1 |

**Color key**

| |
|---|
| 0km to 50km |
| 50km to 100km |
| 100km to 150km |
| 150km to 200km |
| 200km to 250km |
| 250km to 300km |
| >300km |

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**Group B (1)**

| | Everglades | Breton | Chassahowitzka | St. Marks | Okefenokee | Cape Romain | Wichita Mountain | Caney Creek | Upper Buffalo | Hercules-Glades | Mingo |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Everglades | 0 | 940 | 417 | 625 | 612 | 847 | 2,025 | 1,642 | 1,666 | 1,706 | 1,569 |
| Chassahowitzka | 417 | 650 | 0 | 216 | 225 | 543 | 1,671 | 1,269 | 1,273 | 1,305 | 1,155 |
| Breton Is | 942 | 75 | 624 | 457 | 660 | 948 | 1,085 | 723 | 789 | 852 | 812 |
| St Marks | 623 | 509 | 212 | 8 | 200 | 525 | 1,471 | 1,063 | 1,062 | 1,093 | 945 |
| Okefenokee | 612 | 707 | 225 | 208 | 0 | 339 | 1,619 | 1,201 | 1,175 | 1,194 | 1,013 |
| Wolf Island | 661 | 799 | 309 | 306 | 101 | 239 | 1,673 | 1,252 | 1,213 | 1,224 | 1,029 |
| Caney Creek | 1,635 | 748 | 1,261 | 1,050 | 1,194 | 1,348 | 430 | 8 | 177 | 267 | 457 |
| Wichita Mountain | 2,015 | 1,089 | 1,661 | 1,455 | 1,608 | 1,767 | 11 | 413 | 509 | 558 | 806 |
| Upper Buffalo | 1,667 | 835 | 1,273 | 1,058 | 1,176 | 1,287 | 520 | 175 | 0 | 91 | 303 |
| Linville Gorge | 1,174 | 1,018 | 796 | 678 | 573 | 388 | 1,538 | 1,128 | 1,022 | 995 | 750 |
| Hercules-Glades | 1,710 | 909 | 1,309 | 1,093 | 1,196 | 1,281 | 573 | 273 | 100 | 9 | 248 |
| Mingo | 1,572 | 877 | 1,159 | 947 | 1,018 | 1,062 | 813 | 455 | 299 | 247 | 5 |

**Color key**

| |
|---|
| 0km to 50km |
| 50km to 100km |
| 100km to 150km |
| 150km to 200km |
| 200km to 250km |
| 250km to 300km |
| >300km |

48

## Group B (2)

| | Sipsey | Cohutta | Shining Rock | Great Smoky Mtns. | Linville Gorge | Mammoth Cave | James River Face | Seney | Boundary Waters | Isle Royale | Voyageurs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sipsey | 0 | 254 | 433 | 342 | 525 | 327 | 795 | 1,331 | 1,550 | 1,458 | 1,628 |
| Cohutta | 261 | 16 | 173 | 98 | 267 | 283 | 547 | 1,268 | 1,556 | 1,424 | 1,647 |
| Shining Rock | 433 | 182 | 0 | 109 | 100 | 359 | 385 | 1,240 | 1,570 | 1,413 | 1,667 |
| Joyce Kilmer-Slickrock | 328 | 92 | 111 | 23 | 197 | 270 | 471 | 1,217 | 1,522 | 1,380 | 1,615 |
| Great Smoky Mtns | 341 | 113 | 109 | 0 | 186 | 259 | 455 | 1,195 | 1,503 | 1,359 | 1,597 |
| Linville Gorge | 526 | 278 | 97 | 188 | 10 | 406 | 288 | 1,205 | 1,556 | 1,386 | 1,656 |
| Mammoth Cave | 339 | 300 | 359 | 260 | 396 | 12 | 583 | 1,007 | 1,271 | 1,150 | 1,360 |
| Seney | 1,327 | 1,280 | 1,238 | 1,193 | 1,193 | 1,014 | 1,102 | 7 | 455 | 209 | 567 |
| Isle Royale | 1,515 | 1,506 | 1,488 | 1,430 | 1,454 | 1,223 | 1,388 | 303 | 175 | 91 | 279 |
| Boundary Waters Canoe | 1,550 | 1,569 | 1,570 | 1,503 | 1,546 | 1,278 | 1,506 | 459 | 0 | 257 | 112 |
| Voyageurs | 1,655 | 1,688 | 1,697 | 1,626 | 1,677 | 1,395 | 1,646 | 601 | 144 | 395 | 32 |

**Color key**

| |
|---|
| 0km to 50km |
| 50km to 100km |
| 100km to 150km |
| 150km to 200km |
| 200km to 250km |
| 250km to 300km |
| >300km |

49

# Group C 1

| | Big Bend | Chiricahua | Guadalupe Mountains | Saguaro - East | Gila | White Mountain | Salt Creek | Tonto | Mount Baldy | Bosque del Apache | Ike's Backbone | Sierra Ancha | Sycamore Canyon | Petrified Forest |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Big Bend | 1 | 665 | 320 | 790 | 647 | 512 | 474 | 893 | 793 | 613 | 979 | 906 | 1,050 | 891 |
| Guadalupe Mts. | 321 | 434 | 1 | 562 | 357 | 194 | 184 | 625 | 499 | 296 | 701 | 627 | 761 | 586 |
| Chircahua W | 648 | 22 | 422 | 144 | 182 | 394 | 491 | 265 | 247 | 319 | 358 | 295 | 445 | 363 |
| Chircahua NM | 667 | 0 | 434 | 129 | 173 | 396 | 494 | 244 | 228 | 315 | 337 | 273 | 423 | 343 |
| Carlsbad Caverns | 338 | 464 | 46 | 591 | 372 | 177 | 146 | 643 | 510 | 293 | 715 | 641 | 771 | 589 |
| Gila | 649 | 172 | 358 | 261 | 1 | 254 | 359 | 271 | 145 | 148 | 342 | 268 | 405 | 249 |
| White Mountain | 528 | 372 | 207 | 482 | 226 | 28 | 133 | 491 | 340 | 104 | 550 | 479 | 595 | 403 |
| Salt Creek | 491 | 502 | 201 | 617 | 362 | 109 | 17 | 625 | 472 | 232 | 681 | 611 | 720 | 523 |
| Bosque del Apache | 606 | 311 | 288 | 407 | 145 | 125 | 228 | 397 | 243 | 9 | 453 | 382 | 496 | 306 |
| Mount Baldy | 807 | 235 | 512 | 242 | 159 | 380 | 484 | 152 | 13 | 252 | 197 | 127 | 249 | 108 |
| Petrified Forest | 892 | 343 | 585 | 335 | 250 | 429 | 526 | 201 | 117 | 300 | 194 | 154 | 201 | 0 |
| Bandelier | 775 | 509 | 458 | 576 | 337 | 265 | 309 | 503 | 347 | 219 | 520 | 467 | 523 | 328 |
| Pecos | 770 | 556 | 461 | 629 | 383 | 273 | 296 | 561 | 404 | 254 | 579 | 526 | 581 | 387 |
| San Pedro Parks | 828 | 514 | 509 | 568 | 346 | 315 | 367 | 479 | 331 | 249 | 486 | 439 | 480 | 292 |
| Mesa Verde | 1,006 | 583 | 685 | 596 | 443 | 494 | 557 | 461 | 360 | 399 | 430 | 412 | 389 | 263 |

**Color key**

| |
|---|
| 0km to 50km |
| 50km to 100km |
| 100km to 150km |
| 150km to 200km |
| 200km to 250km |
| 250km to 300km |
| >300km |

50

# Group C2

| Group C2 | San Pedro Parks | Bandelier | Grand Canyon, Hance | Wheeler Peak | Mesa Verde | Bryce Canyon | Weminuche | Great Sand Dunes | Capitol Reef | Canyonlands | White River | Rocky Mountain | Mount Zirkel |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| White Mountain | 295 | 257 | 628 | 345 | 477 | 736 | 496 | 471 | 727 | 659 | 635 | 753 | 786 |
| Salt Creek | 350 | 297 | 745 | 344 | 546 | 836 | 546 | 468 | 813 | 728 | 653 | 747 | 795 |
| Bosque del Apache | 247 | 227 | 531 | 334 | 407 | 645 | 438 | 452 | 643 | 584 | 595 | 729 | 749 |
| Petrified Forest | 285 | 328 | 225 | 424 | 262 | 356 | 337 | 481 | 384 | 376 | 523 | 687 | 665 |
| Bandelier | 58 | 0 | 517 | 115 | 254 | 567 | 249 | 226 | 528 | 434 | 377 | 503 | 529 |
| Pecos | 109 | 59 | 573 | 75 | 291 | 613 | 272 | 199 | 568 | 465 | 373 | 483 | 519 |
| San Pedro Parks | 11 | 61 | 467 | 133 | 193 | 508 | 193 | 213 | 467 | 373 | 338 | 476 | 492 |
| Wheeler Peak | 142 | 116 | 594 | 3 | 282 | 612 | 244 | 128 | 555 | 442 | 312 | 412 | 454 |
| Mesa Verde | 198 | 254 | 342 | 279 | 1 | 330 | 79 | 269 | 276 | 183 | 261 | 426 | 402 |
| Weminuche | 201 | 249 | 418 | 240 | 79 | 387 | 1 | 201 | 316 | 199 | 188 | 351 | 335 |
| Great Sand Dunes | 224 | 226 | 609 | 127 | 269 | 588 | 201 | 0 | 512 | 386 | 195 | 283 | 328 |
| La Garita | 216 | 247 | 512 | 194 | 171 | 475 | 93 | 117 | 395 | 270 | 132 | 280 | 286 |
| Black Canyon of Gunnison | 295 | 336 | 478 | 297 | 168 | 407 | 103 | 213 | 316 | 186 | 99 | 264 | 235 |
| West Elk | 299 | 333 | 522 | 279 | 201 | 453 | 126 | 182 | 361 | 231 | 61 | 226 | 210 |
| Arches | 380 | 433 | 366 | 430 | 187 | 255 | 191 | 371 | 154 | 29 | 246 | 392 | 327 |
| Maroon Bells | 348 | 378 | 578 | 309 | 262 | 499 | 187 | 195 | 401 | 272 | 0 | 166 | 154 |
| Eagles Nest | 411 | 434 | 653 | 352 | 339 | 565 | 263 | 227 | 464 | 338 | 77 | 89 | 101 |
| Flat Tops | 441 | 473 | 609 | 407 | 326 | 502 | 261 | 291 | 396 | 279 | 98 | 149 | 80 |

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**Color key**

- 0km to 50km
- 50km to 100km
- 100km to 150km
- 150km to 200km
- 200km to 250km
- 250km to 300km
- >300km

**Group D1**

| | Great Sand Dunes | White River | Rocky Mtn | Mount Zirkel | Bridger | Yellowstone | North Absoraka |
|---|---|---|---|---|---|---|---|
| Rocky Mountain | 283 | 166 | 0 | 100 | 462 | 622 | 588 |
| Mount Zirkel | 330 | 155 | 102 | 2 | 371 | 540 | 515 |
| Rawah | 332 | 187 | 58 | 65 | 406 | 564 | 530 |
| Bridger | 685 | 491 | 461 | 373 | 0 | 184 | 199 |
| Fitzpatrick | 705 | 512 | 472 | 387 | 36 | 159 | 165 |
| Washakie | 772 | 581 | 527 | 449 | 109 | 94 | 90 |
| North Absoraka | 860 | 671 | 608 | 535 | 200 | 54 | 32 |

**Group D2**

| | Wind Cave | Badlands | Gates of the Mtn. | Theodore Roosevelt | UL Bend | Medicine Lake | Lostwood |
|---|---|---|---|---|---|---|---|
| Wind Cave | 1 | 126 | 742 | 372 | 606 | 554 | 572 |
| Badlands | 126 | 0 | 839 | 368 | 679 | 562 | 546 |
| North Absoraka | 521 | 636 | 274 | 550 | 323 | 579 | 709 |
| Theodore Roosevelt | 418 | 427 | 588 | 65 | 357 | 137 | 191 |
| UL Bend | 560 | 626 | 302 | 348 | 64 | 274 | 425 |
| Medicine Lake | 553 | 559 | 588 | 191 | 346 | 14 | 140 |
| Lostwood | 566 | 542 | 720 | 201 | 478 | 148 | 7 |

## Group E1

| | Saguaro - East | Chiricahua | Tonto | Gila | Ike's Backbone | Sierra Ancha | Mount Baldy | Sycamore Canyon |
|---|---|---|---|---|---|---|---|---|
| Saguaro - East | **9** | 130 | 160 | 259 | 248 | 205 | 235 | 341 |
| Galiuro | 58 | **107** | 142 | 210 | 235 | 180 | 186 | 325 |
| Superstition | 166 | 242 | **2** | 272 | 95 | 53 | 161 | 186 |
| Sierra Ancha | 184 | 246 | 28 | 256 | 94 | **31** | 136 | 178 |
| Sycamore Canyon | 334 | 411 | 169 | 400 | 77 | 139 | 257 | **17** |
| Mazatzal | 205 | 286 | 42 | 308 | **52** | 49 | 186 | 145 |
| Pine Mountain | 258 | 341 | 97 | 353 | **11** | 83 | 220 | 94 |
| Grand Canyon | 438 | 502 | 270 | 461 | 184 | 230 | 315 | 93 |
| Zion NP | 602 | 672 | 436 | 626 | 345 | 398 | 481 | 252 |
| Bryce Canyon | 620 | 675 | 451 | 607 | 367 | 408 | 467 | 276 |

## Group E2

| | Petrified Forest | Grand Canyon, | Zion Canyon | Bryce Canyon | Capitol Reef | Canyonlands | Mesa Verde | Weminuche |
|---|---|---|---|---|---|---|---|---|
| Galiuro | 285 | 410 | 577 | 588 | 645 | 659 | 544 | 614 |
| Superstition | 202 | 273 | 438 | 454 | 520 | 550 | 463 | 540 |
| Sierra Ancha | 174 | 260 | 429 | 439 | 500 | 526 | 435 | 512 |
| Sycamore Canyon | 204 | 110 | 267 | 293 | 374 | 433 | 401 | 482 |
| Mazatzal | 201 | 234 | 397 | 417 | 488 | 526 | 453 | 532 |
| Pine Mountain | 205 | 186 | 344 | 369 | 446 | 495 | 440 | 520 |
| Grand Canyon | 224 | **1** | 172 | 184 | 266 | 337 | 342 | 419 |
| Zion NP | 379 | 169 | **14** | 85 | 191 | 312 | 403 | 465 |
| Bryce Canyon | 356 | 183 | 98 | **0** | 109 | 227 | 330 | 388 |
| Capitol Reef | 383 | 278 | 226 | 129 | **22** | 108 | 261 | 297 |

| Group E3 | Agua Tibia | San Gabriel | San Gorgonio | Joshua Tree | San Rafael | Dome Land | Pinnacles | Sequoia | Kaiser | Hoover | Yosemite | Bliss | Point Reyes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agua Tibia | 6 | 138 | 87 | 91 | 316 | 278 | 512 | 381 | 467 | 556 | 537 | 678 | 749 |
| San Jacinto | 44 | 141 | 55 | 43 | 328 | 258 | 511 | 363 | 447 | 532 | 519 | 657 | 745 |
| Joshua Tree | 97 | 173 | 70 | 19 | 360 | 259 | 528 | 363 | 444 | 524 | 517 | 651 | 757 |
| San Gorgonio | 80 | 104 | 1 | 49 | 292 | 205 | 463 | 310 | 394 | 479 | 466 | 604 | 695 |
| Cucamonga | 103 | 42 | 61 | 111 | 230 | 172 | 409 | 273 | 359 | 450 | 430 | 571 | 645 |
| San Gabriel | 127 | 9 | 95 | 145 | 197 | 163 | 382 | 259 | 345 | 438 | 414 | 557 | 619 |
| San Rafael | 301 | 174 | 276 | 326 | 17 | 186 | 224 | 210 | 278 | 372 | 326 | 467 | 463 |
| Dome Land | 272 | 157 | 204 | 245 | 198 | 5 | 281 | 105 | 189 | 279 | 261 | 401 | 499 |
| Sequoia | 377 | 255 | 309 | 349 | 223 | 106 | 209 | 1 | 85 | 179 | 156 | 297 | 405 |
| Kings Canyon | 406 | 288 | 336 | 373 | 258 | 133 | 218 | 37 | 57 | 145 | 130 | 267 | 395 |
| Kaiser | 468 | 347 | 399 | 437 | 292 | 196 | 197 | 93 | 7 | 90 | 67 | 205 | 342 |
| John Muir | 467 | 351 | 395 | 430 | 313 | 195 | 230 | 100 | 34 | 83 | 85 | 208 | 368 |
| Ansel Adams | 506 | 387 | 435 | 471 | 332 | 233 | 217 | 133 | 48 | 49 | 45 | 167 | 331 |
| Yosemite | 532 | 408 | 464 | 503 | 332 | 261 | 188 | 156 | 73 | 62 | 0 | 145 | 286 |
| Hoover | 565 | 445 | 494 | 529 | 381 | 292 | 238 | 191 | 105 | 25 | 52 | 109 | 304 |
| Emigrant | 582 | 460 | 512 | 549 | 385 | 310 | 228 | 207 | 121 | 52 | 54 | 91 | 277 |
| Mokelumne | 597 | 484 | 522 | 554 | 436 | 326 | 299 | 233 | 151 | 56 | 113 | 103 | 343 |

| Group F1 | Jarbidge | Bridger | Craters of the Moon | Sawtooth | Yellowstone | Three Sisters | Hells Canyon | North Absoraka |
|---|---|---|---|---|---|---|---|---|
| Jarbidge | **0** | 481 | 232 | 257 | 505 | 604 | 361 | 584 |
| Craters of the Moon | 233 | 313 | **1** | 135 | 281 | 691 | 312 | 363 |
| Grand Teton | 432 | 111 | 229 | 341 | **102** | 912 | 508 | 160 |
| Teton W | 492 | 128 | 280 | 380 | **56** | 950 | 539 | 97 |
| Sawtooth | 257 | 438 | 136 | **1** | 363 | 571 | 176 | 445 |
| Yellowstone | 504 | 183 | 281 | 363 | **2** | 929 | 512 | 83 |
| Strawberry Mountain | 380 | 739 | 427 | 305 | 664 | 266 | 167 | 745 |
| Red Rock Lakes | 432 | 245 | 200 | 263 | **104** | 826 | 408 | 184 |
| Eagle Cap | 388 | 648 | 350 | 214 | 548 | 389 | 38 | 626 |
| Hells Canyon | 395 | 605 | 319 | 184 | 494 | 451 | **46** | 570 |
| Selway-Bitterroot | 456 | 465 | 269 | 202 | 317 | 659 | 244 | 383 |
| Anaconda-Pintler | 482 | 443 | 280 | 234 | 284 | 706 | 291 | 345 |
| Gates of the Mountains | 624 | 462 | 403 | 386 | 279 | 850 | 444 | 302 |

**Color key**

| | |
|---|---|
| 0km to 50km | |
| 50km to 100km | |
| 100km to 150km | |
| 150km to 200km | |
| 200km to 250km | |
| 250km to 300km | |
| >300km | |

Why isn't Eagle Cap represented by Hells Canyon, instead of grouped with Strawberry Mtn?

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## Group F2

| | Mount Hood | Starkey | Sula | Monture | Gates of the Mountains | UL Bend | Cabinet Mountains | Glacier |
|---|---|---|---|---|---|---|---|---|
| Craters of the Moon | 688 | 442 | 268 | 407 | 400 | 593 | 526 | 562 |
| Sawtooth | 559 | 308 | 201 | 355 | 387 | 612 | 424 | 487 |
| Yellowstone | 904 | 646 | 318 | 357 | 273 | 361 | 555 | 519 |
| Strawberry Mountain | 267 | **105** | 411 | 536 | 616 | 857 | 471 | 594 |
| Red Rock Lakes | 800 | 542 | 224 | 295 | 240 | 397 | 476 | 462 |
| Eagle Cap | 356 | **97** | 271 | 391 | 473 | 715 | 341 | 455 |
| Hells Canyon | 411 | 153 | 209 | 330 | 411 | 652 | 299 | 404 |
| Selway-Bitterroot | 613 | 360 | **0** | 155 | 206 | 446 | 266 | 295 |
| Anaconda-Pintler | 659 | 407 | **47** | 129 | 162 | 401 | 279 | 285 |
| Gates of the Mountains | 793 | 551 | 202 | 106 | **9** | 247 | 315 | 245 |
| Scapegoat | 731 | 497 | 175 | **33** | 86 | 306 | 238 | 177 |
| Mission Mountains | 656 | 434 | 172 | **61** | 174 | 387 | 150 | 124 |
| Bob Marshall | 702 | 484 | 215 | **72** | 163 | 350 | 173 | 96 |
| Cabinet Mountains | 569 | 396 | 292 | 227 | 338 | 527 | **29** | 131 |
| Glacier | 695 | 503 | 295 | 167 | 254 | 406 | 139 | **0** |

## Color key

| |
|---|
| 0km to 50km |
| 50km to 100km |
| 100km to 150km |
| 150km to 200km |
| 200km to 250km |
| 250km to 300km |
| >300km |

56

| Group G1 | San Rafael | Dome Land | Pinnacles | Sequoia | Kaiser | Yosemite | Point Reyes | Hoover | Bliss | Lassen Volcanic | Trinity | Red wood |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ventana | 218 | 316 | **48** | 249 | 244 | 236 | 242 | 298 | 333 | 479 | 518 | 631 |
| Pinnacles | 220 | 285 | **0** | 209 | 196 | 188 | 239 | 250 | 292 | 452 | 498 | 618 |
| Point Reyes | 456 | 500 | 238 | 404 | 345 | 284 | **1** | 327 | 262 | 292 | 296 | 395 |
| Desolation | 471 | 402 | 292 | 299 | 213 | 145 | 261 | 129 | **1** | 214 | 305 | 443 |
| Yolla Bolly Middle Eel | 651 | 645 | 432 | 540 | 461 | 388 | 221 | 397 | 276 | 127 | **76** | 187 |
| Caribou | 648 | 593 | 446 | 490 | 404 | 335 | 303 | 319 | 193 | **34** | 141 | 271 |
| Lassen Volcanic | 659 | 613 | 451 | 509 | 424 | 353 | 292 | 342 | 214 | **0** | 108 | 240 |
| Thousand Lakes | 677 | 629 | 469 | 525 | 440 | 369 | 308 | 356 | 229 | **18** | 104 | 231 |
| South Warner | 733 | 648 | 544 | 551 | 465 | 404 | 425 | 371 | 262 | 145 | 227 | 325 |
| Marble Mountain | 804 | 780 | 587 | 675 | 591 | 519 | 378 | 514 | 387 | 175 | **88** | 73 |
| Redwood | 837 | 828 | 617 | 723 | 641 | 568 | 394 | 569 | 443 | 239 | 137 | **1** |
| Lava Beds | 783 | 721 | 581 | 619 | 533 | 466 | 420 | 443 | 321 | 132 | 160 | 229 |
| Kalmiopsis | 903 | 883 | 685 | 778 | 694 | 621 | 468 | 616 | 488 | 275 | 190 | 80 |
| Mountain Lakes | 864 | 811 | 655 | 708 | 622 | 553 | 473 | 534 | 410 | 205 | 182 | 185 |
| Gearhart Mountain | 864 | 787 | 667 | 689 | 603 | 539 | 515 | 509 | 395 | 225 | 250 | 287 |
| Crater Lake | 925 | 867 | 717 | 766 | 679 | 611 | 534 | 590 | 468 | 266 | 241 | 219 |
| Diamond Peak | 993 | 931 | 786 | 830 | 744 | 677 | 604 | 653 | 533 | 335 | 310 | 273 |

**Color key**

| |
|---|
| 0km to 50km |
| 50km to 100km |
| 100km to 150km |
| 150km to 200km |
| 200km to 250km |
| 250km to 300km |
| >300km |

| Group G2 | Lava Beds | Kalmiopsis | Crater Lake | Three Sisters | Mount Hood | Starkey | Mount Rainier | White Pass | Snoqualmie Pass | Olympic | North Cascades | Pasayten |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yolla Bolly Middle Eel | 216 | 286 | 317 | 470 | 583 | 675 | 741 | 735 | 821 | 877 | 969 | 951 |
| Caribou | 137 | 331 | 278 | 427 | 534 | 569 | 699 | 681 | 769 | 846 | 915 | 882 |
| Lassen Volcanic | 130 | 305 | 266 | 419 | 528 | 578 | 692 | 676 | 765 | 837 | 911 | 882 |
| Thousand Lakes | 113 | 291 | 248 | 401 | 510 | 562 | 674 | 658 | 747 | 819 | 893 | 864 |
| South Warner | 117 | 347 | 236 | 362 | 458 | 454 | 622 | 596 | 684 | 774 | 825 | 785 |
| Marble Mountain | 143 | 134 | 177 | 322 | 434 | 561 | 588 | 585 | 671 | 721 | 819 | 806 |
| Redwood | 215 | 110 | 218 | 346 | 454 | 607 | 598 | 602 | 685 | 722 | 831 | 826 |
| Lava Beds | 14 | 243 | 147 | 292 | 399 | 452 | 564 | 546 | 634 | 711 | 780 | 750 |
| Kalmiopsis | 210 | 33 | 163 | 272 | 377 | 546 | 519 | 524 | 605 | 642 | 752 | 748 |
| Mountain Lakes | 86 | 162 | 62 | 217 | 329 | 432 | 491 | 479 | 567 | 633 | 715 | 693 |
| Gearhart Mountain | 102 | 264 | 115 | 222 | 320 | 357 | 485 | 461 | 550 | 635 | 694 | 659 |
| Crater Lake | 141 | 162 | 0 | 155 | 267 | 389 | 429 | 418 | 506 | 572 | 654 | 634 |
| Diamond Peak | 208 | 193 | 70 | 85 | 197 | 342 | 359 | 348 | 436 | 502 | 584 | 565 |
| Three Sisters | 290 | 253 | 155 | 0 | 113 | 298 | 274 | 264 | 351 | 419 | 499 | 483 |
| Mount Washington | 289 | 263 | 157 | 14 | 110 | 285 | 274 | 261 | 349 | 421 | 496 | 478 |
| Mount Jefferson | 316 | 286 | 185 | 33 | 82 | 273 | 246 | 233 | 321 | 394 | 468 | 451 |
| Mount Hood | 408 | 367 | 278 | 124 | 13 | 250 | 157 | 140 | 228 | 308 | 376 | 360 |
| Mt Adams | 497 | 453 | 369 | 215 | 103 | 256 | 79 | 49 | 137 | 231 | 284 | 272 |
| Goat Rocks | 536 | 488 | 408 | 254 | 141 | 273 | 55 | 12 | 98 | 198 | 246 | 236 |
| Mount Rainier | 562 | 492 | 429 | 274 | 165 | 327 | 0 | 58 | 91 | 153 | 233 | 245 |
| Olympic | 640 | 533 | 501 | 351 | 256 | 439 | 112 | 168 | 145 | 81 | 231 | 282 |
| Alpine Lakes | 635 | 580 | 506 | 352 | 239 | 331 | 91 | 89 | 1 | 133 | 148 | 155 |
| Glacier Peak | 723 | 671 | 597 | 442 | 330 | 384 | 181 | 178 | 92 | 146 | 58 | 85 |
| North Cascades | 759 | 696 | 630 | 475 | 362 | 431 | 205 | 213 | 124 | 128 | 35 | 113 |
| Pasayten | 797 | 752 | 673 | 520 | 407 | 431 | 262 | 256 | 172 | 204 | 42 | 67 |

**Group H1**

| | Hawaii Volcanoes | Haleakala |
|---|---|---|
| Hawaii Volcanoes | **1** | 186 |
| Haleakala | 187 | **0** |

**Group H2**

| | Simeonof | Tuxedni | Denali |
|---|---|---|---|
| Simeonof | **89** | 694 | 1,143 |
| Tuxedni | 716 | **19** | 436 |
| Denali | 1,140 | 454 | **0** |
| Bering Sea | 921 | 1,117 | 1,317 |

**Color key**

| |
|---|
| 0km to 50km |
| 50km to 100km |
| 100km to 150km |
| 150km to 200km |
| 200km to 250km |
| 250km to 300km |
| >300km |