Selected Results from 2003 Visibility Data for CENRAP States

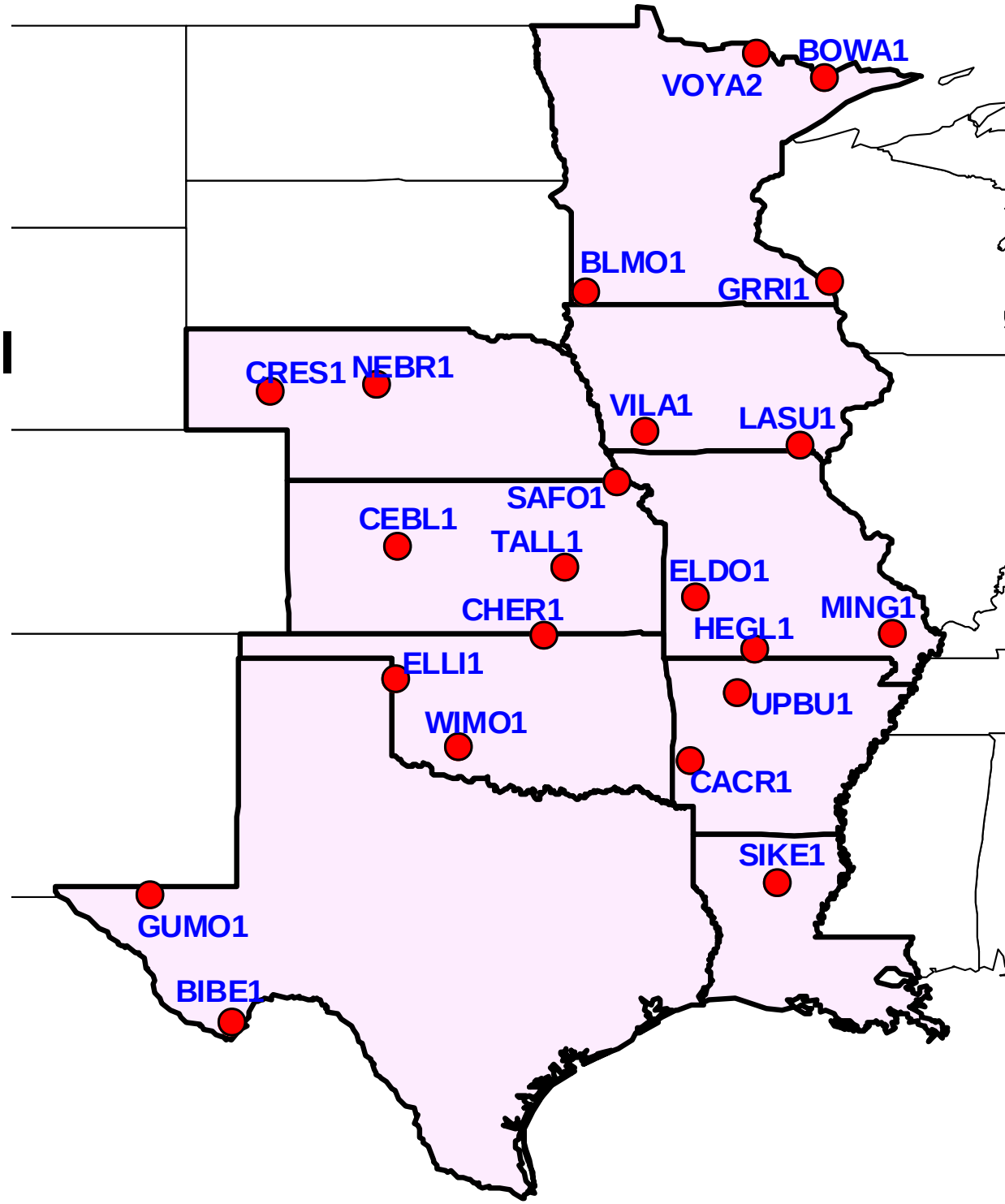
Data obtained from:

http://vista.cira.colostate.edu/views/Web/AnnualSummary/ContourMaps.aspx

Extracted on: 3/28/2004

CENRAP Visibility Monitoring Sites with Graphical Data Availabl for 2003

All data presented is from the worst 20% of visibility days recorded in 2003.



Background on Visibility (IMPROVE Protocol) Monitoring

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program is a cooperative measurement effort governed by a steering committee composed of representatives from Federal and regional-state organizations. The IMPROVE monitoring program was established in 1985 to aid the creation of Federal and State implementation plans for the protection of visibility in Class I areas (156 national parks and wilderness areas) as stipulated in the 1977 amendments to the Clean Air Act.

With the enactment of the regional haze rules the IMPROVE monitoring network was expanded to better evaluate visibility related pollution in areas of the country with few Class I areas.

Iowa installed two IMPROVE Protocol sampling sites and began collecting data in June of 2002. Several other sites in the 9 state CENRAP (CENtral Regional Air Planning Association) also installed IMPROVE monitors during the same time frame.

The following pages contain National maps and graphs of data from IMPROVE monitors in the CENRAP region for the 2003 calendar year.

IMPROVE Monitoring Equipment and Frequency

The standard IMPROVE sampler consists of four independent filter modules which are operated for 24 hours every third day. The various modules collect aerosol particulate in either PM10 (particulate less than 10 microns in diameter) or PM2.5 (particulate less than 2.5 microns in diameter) on various filter substrates for chemical analysis.

- Module A: PM2.5 particles on Teflon. These are analyzed by five methods at UC Davis for: Gravimetric Mass for PM2.5, Optical absorption, hydrogen by PESA, Elements Na-Mn by PIXE, and Elements Fe-Pb by XRF

- Module B: PM2.5 particles on nylon. A denuder before the nylon filter removes nitric acid vapors. These are analyzed by ion chromatography for nitrate, chloride, sulfate and nitrite.

- Module C: PM2.5 particles on quartz. These are analyzed at DRI for carbon using the Thermal Optical Reflectance (TOR). A secondary filter at is used to determine artifact.

- Module D: PM10 particles on Teflon for gravimetric analysis

A Little about Visibility Terminology

The most popular term to characterize visibility is standard visual range (SVR) which is the greatest distance at which a large black object can just be seen against the horizon sky. The first graphic depicts the calculated average standard visual range (in kilometers) on the worst 20% of measured visibility days in 2003. This graphic indicates that on a typical high particulate day in Iowa the SVR would be about 20-30 km or around 12-19 miles. Estimates of historic average visual range prior to pollution caused by mankind vary from 60-80 miles in the Eastern United States to 110-115 miles in the Western U.S.

Most in the technical community prefer to use the term extinction coefficient (b_{ext}) to describe the amount of visibility impairment. This coefficient describes the loss of image-forming light per unit distance due to scattering and absorption by particles and gases in the atmosphere. The distance commonly used for extinction coefficient data is the inverse megameter (Mm^{-1}). A high extinction coefficient indicates that there is greater visibility impairment per million meters of atmosphere. The second graphic indicates that typical impairment in Iowa on the 20% worst days is 125-150 Mm^{-1}. For comparison we can see that in Utah the impairment is only about 19-35 Mm^{-1}.

Calculating Light Extinction

As detailed in EPA's visibility rule, the amount of haze at monitoring site on a given day can be determined from the concentrations of certain chemical constituents of $PM_{2.5}$ (ammonium sulfate, ammonium nitrate, organic carbon, elemental carbon, and soils) and the coarse mass (PM_{10}-$PM_{2.5}$).

These concentrations, along with an estimate of the relative humidity at the site, are then used to calculate the light extinction coefficients (b_{ext}'s) for each species. Summing the b_{ext}'s gives the total light extinction coefficient b_{total}, a measure of the visibility impairment:

$$b_{total}=b_{ammonium\ sulfate}+b_{ammonium\ nitrate}+b_{organic\ carbon}+b_{elemental\ carbon}+b_{soils}+b_{coarse\ mass}$$

The higher b_{total}, the poorer the visibility is at the site on a given day. The ratio of each b to b_{total} provides a measure of the contribution of each haze constituent to the total extinction on a given day.

The regional haze rule uses the visibility on the worst 20% of monitoring days in a year as a measure of "worst case" visibility. The maps that follow depict the concentrations and "b fractions" of the haze constituents in the visibility monitoring network on these days with worst haze.

Visibility Degradation

The most prevalent and visibility degrading species in Iowa are ammonium sulfate and ammonium nitrate. In Iowa they accounted for more than 80% of the visibility degradation on the 20% worst monitoring days in 2003. Also included are graphics showing the percent of visibility degradation due to elemental carbon, organic carbon, course mass, and fine soil.

The next set of data are pie charts for each of the IMPROVE sites in the CENRAP region. These charts show the percentage of visibility degradation due to each of the measured aerosol components for the worst 20% of measured days in 2003. The charts also show the average coefficient of extinction for the worst 20% of monitoring data in 2003 for each of the CENRAP sites where data was available.

A chart (from the VIEWS website) of measured and calculated visibility parameters is included on the following pages. This chart includes naming conventions, algorithms used to calculate the value, and descriptions of what the various parameters mean.

Visibility Parameters Chart

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Parameter	Name	Algorithm	Description
MF	PM2.5: mass	Measured quantity	Gravimetric measurement of aerosol fine mass (PM2.5)
MT	PM10: Mass	Measured quantity	Gravimetric measurement of aerosol total mass (PM10)
aerosol_bext	Aerosol extinction	ammSO4f_bext + ammNO3f_bext + OMCf_bext + ECf_bext + SOILf_bext + CM_bext	Sum of major aerosol species mass extinction
ammNO3f	Ammonium nitrate	1.29*NO3f	Ammonium nitrate from nitrate ion
ammNO3f_bext	Ammonium nitrate extinction	3*fRH*ammNO3f	Use mass extinction efficiency of 3m2/g for ammonium nitrate and fRH
ammSO4f	Ammonium sulfate	4.125*Sf	Ammonium sulfate from sulfur element
ammSO4f_bext	Ammonium sulfate extinction	3*fRH*ammSO4f	Use mass extinction efficiency of 3m2/g for ammonium sulfate and fRH
CM	PM2.5-10: mass	MT-MF	Fine mass (PM2.5) subtracted from PM10
CM_bext	Coarse mass extinction	0.6*CM	Use mass extinction efficiency of 0.6 m2/g for coarse mass
dv	Deciview	10*ln((aerosol_bext+10)/10)	Perception based visibility metric
ECf	Carbon: total elemental	E1+E2+E3-OP	Sum of elemental carbon fractions from TOR - OP
ECf_bext	Elemental carbon extinction	10*ECf	Use mass extinction efficiency of 10m2/g for elemental carbon
F_CM_bext	Coarse mass extinction fraction	100*CM_bext/aerosol_bext	Contribution of coarse mass extinction to aerosol extinction
F_EC	Elemental carbon fraction	100*ECf/RCFM	Contribution of fine elemental carbon to reconstructed fine mass
F_EC_bext	Elemental carbon extinction fraction	100*ECf_bext/aerosol_bext	Contribution of fine elemental carbon extinction to aerosol extinction

Visibility Parameter Chart Cont.

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Parameter	Name	Algorithm	Description
F_NO3	Nitrate fraction	100*ammNO3f/RCFM	Contribution of fine ammonium nitrate to reconstructed fine mass
F_NO3_bext	Nitrate extinction fraction	100*ammNO3f_bext/aerosol_bext	Contribution of fine ammonium nitrate extinction to aerosol extinction
F_OMC	Organic carbon mass fraction	100*OMCf/RCFM	Contribution of fine organic mass to reconstructed fine mass
F_OMC_bext	Organic carbon mass extinction fraction	100*OMCf_bext/aerosol_bext	Contribution of fine organic mass extinction to aerosol extinction
F_SO4	Sulfate fraction	100*ammSO4f/RCFM	Contribution of fine ammonium sulfate to reconstructed fine mass
F_SO4_bext	Sulfate extinction fraction	100*ammSO4f_bext/aerosol_bext	Contribution of fine ammonium sulfate extinction to aerosol extinction
F_SOIL	Soil	100*SOILf/RCFM	Contribution of fine soil to reconstructed fine mass
F_SOIL_bext	Soil extinction fraction	100*SOILf_bext/aerosol_bext	Contribution of fine soil extinction to aerosol extinction
fRHgrid	Relative humidity factor	gridded value	Gridded value
OMCf	Organic mass by carbon	1.4*(O1+O2+O3+O4+OP)	Organic carbon mass from OC
OMCf_bext	Organic carbon extinction	4*1.4*OCf	Use mass extinction efficiency of 4 m2/g for organic carbon
RCFM	Reconstructed fine mass	ammSO4f + ammNO3f + ECf + OMCf + SOILf	Fine mass reconstructed from major component species concentrations
RCTM	Reconstructed total mass	ammSO4f + ammNO3f + ECf + OMCf + SOILf + CM	Sum of major fine and coarse aerosol mass concentrations
SOILf	Fine Soil	2.2*Al+2.49*Si+1.63*Ca+2.42*Fe+1.94*Ti	Sum of common oxides of soil elements
SOILf_bext	Fine soil extinction	1*SOILf	Use mass extinction efficiency of 1m2/g for fine soil
SVR	Standard visual range	3910/(aerosol_bext+10)	Standard visual range in kilometers

Species Contributions to Fine Mass

The final section of this document is comprised of graphics which represent the typical mass in micrograms per cubic meter of each of the species that comprise the majority of fine aerosol mass.

The first graphic in this section shows the average mass of $PM_{2.5}$ aerosol on the 20% worst monitoring days in 2003.

The final set of graphics details the mass contribution of several of the major aerosol components to the total mass.

National graphics have been included for:

- Ammonium Sulfate
- Ammonium Nitrate
- Elemental Carbon
- Organic Carbon
- Course Mass
- Fine Soil

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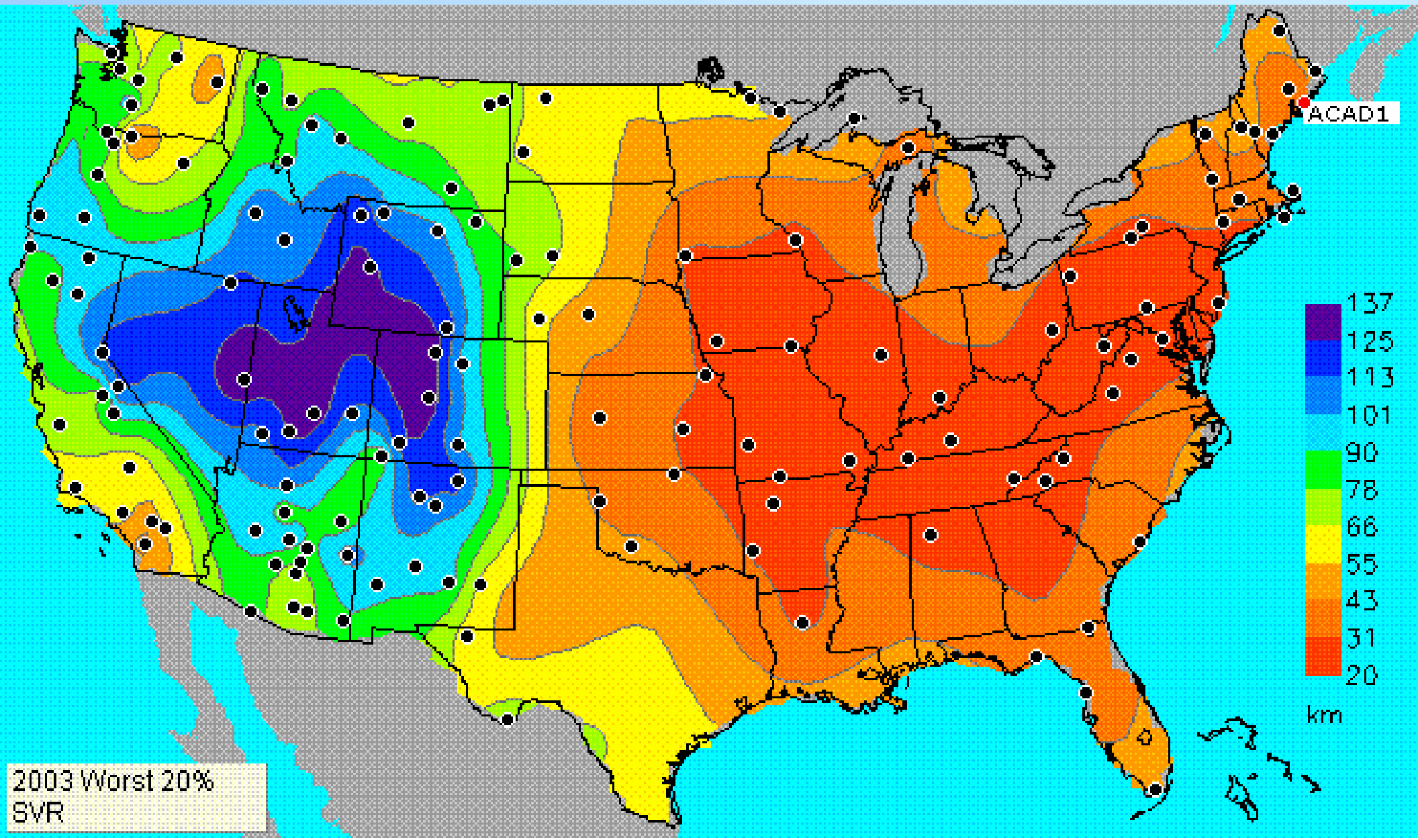
Standard Visual Range on worst 20% of Monitored Days in 2003



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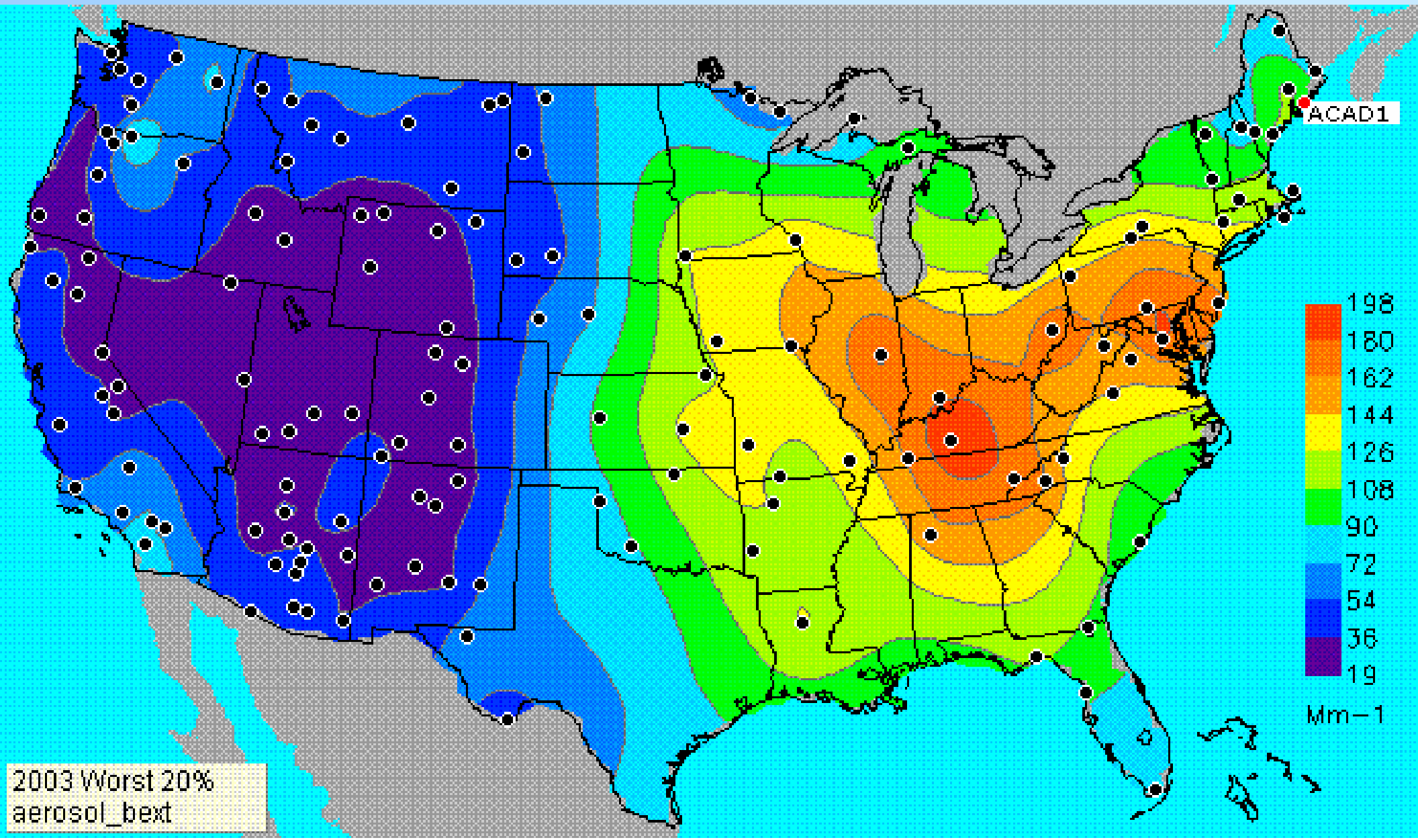
Total Aerosol Extinction on Worst 20% of Monitored Days in 2003



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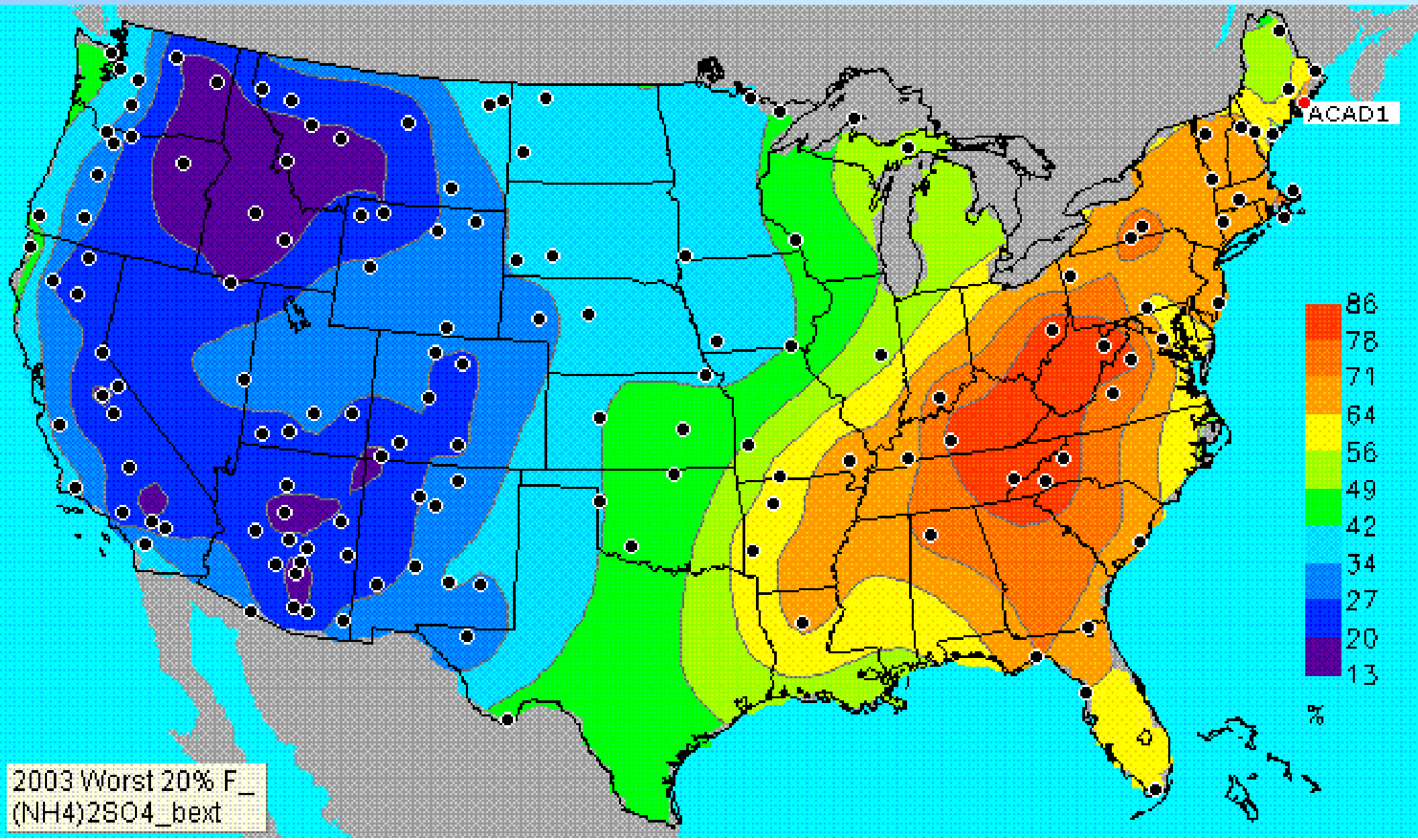
Percent of Visibility Impairment due to Ammonium Sulfate on Worst 20% of Monitored Days



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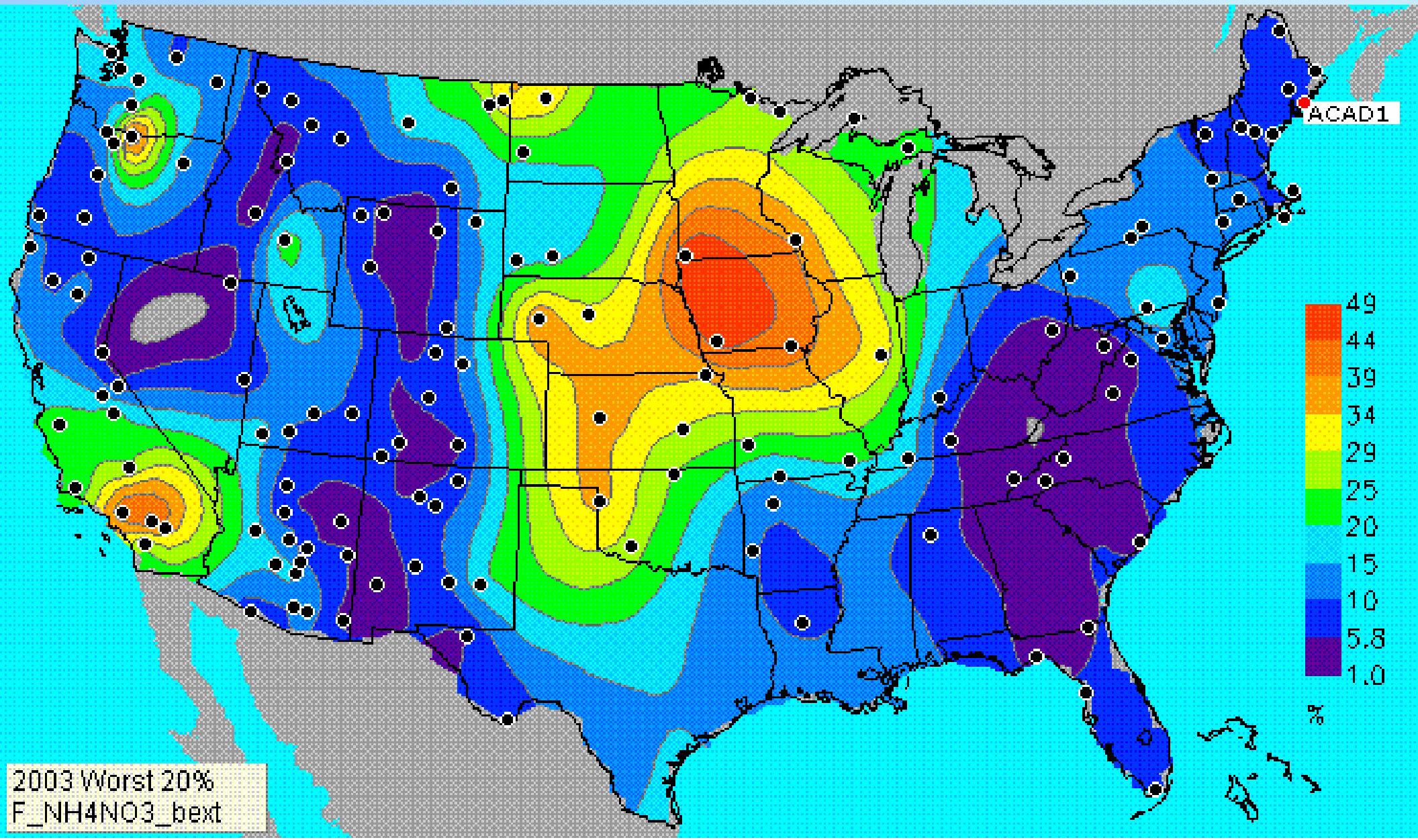
Percent of Visibility Impairment due to Ammonium Nitrate on Worst 20% of Monitored Days



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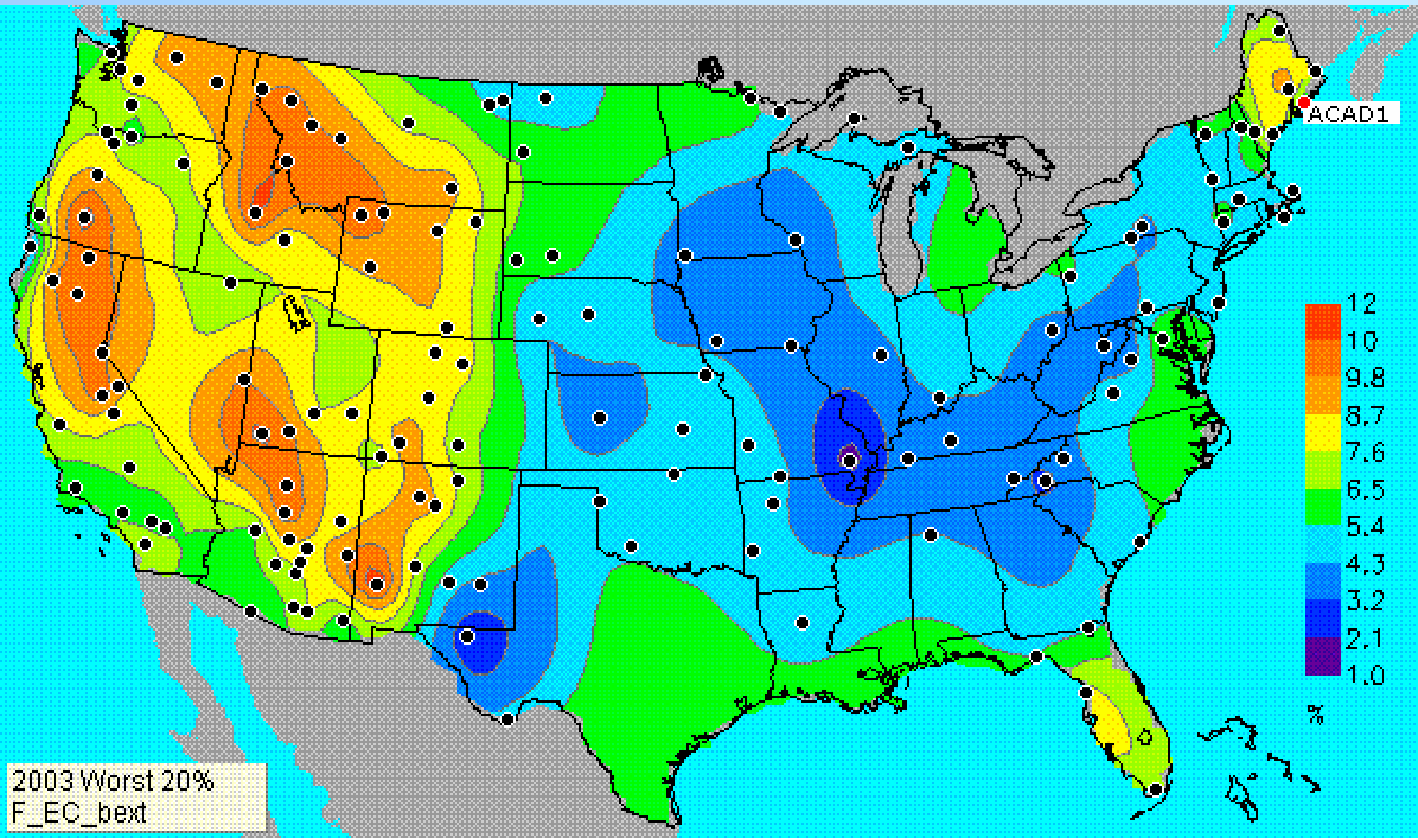
Percent of Visibility Impairment due to Elemental Carbon on Worst 20% of Monitored Days



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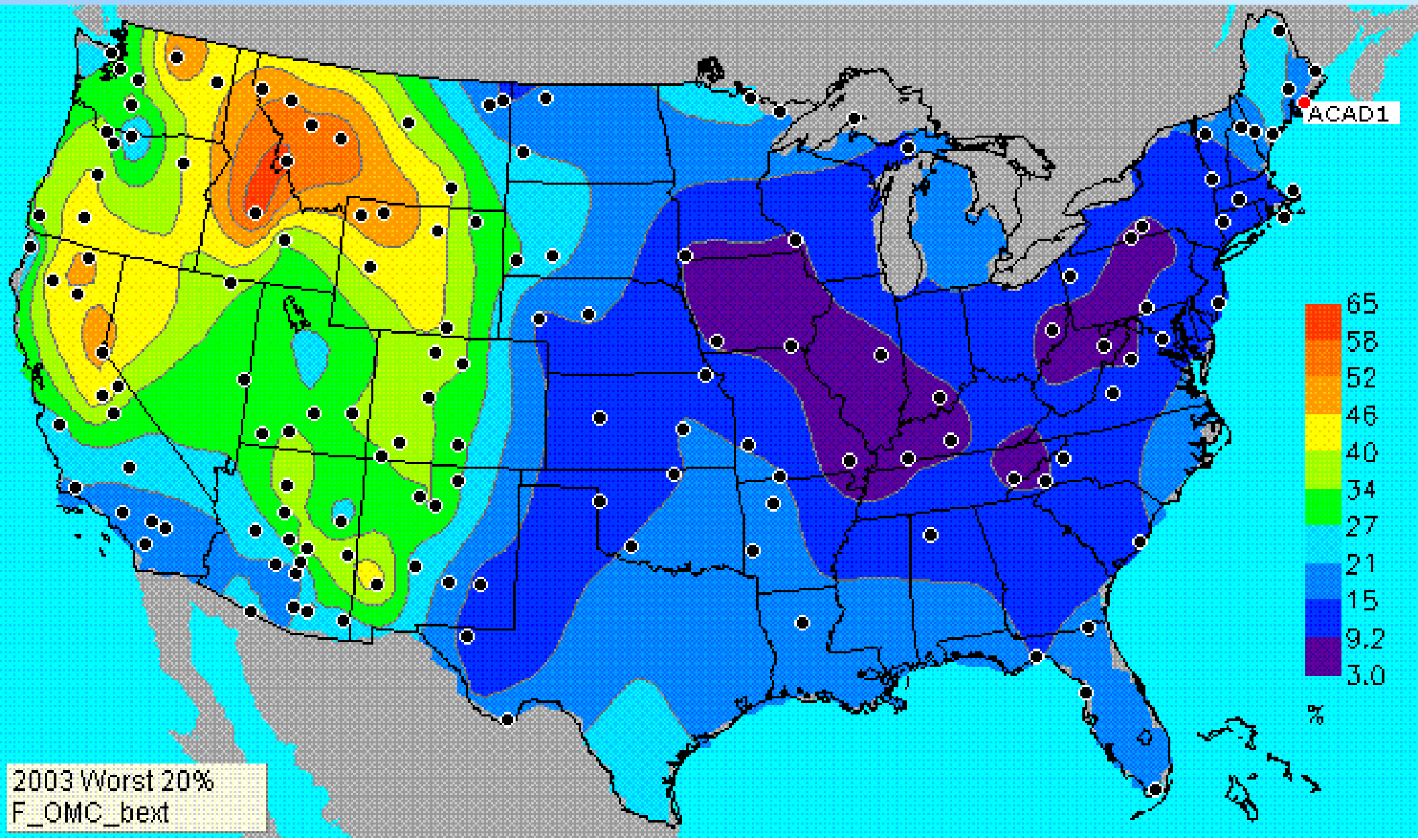
Percent of Visibility Impairment due to Organic Carbon on Worst 20% of Monitored Days



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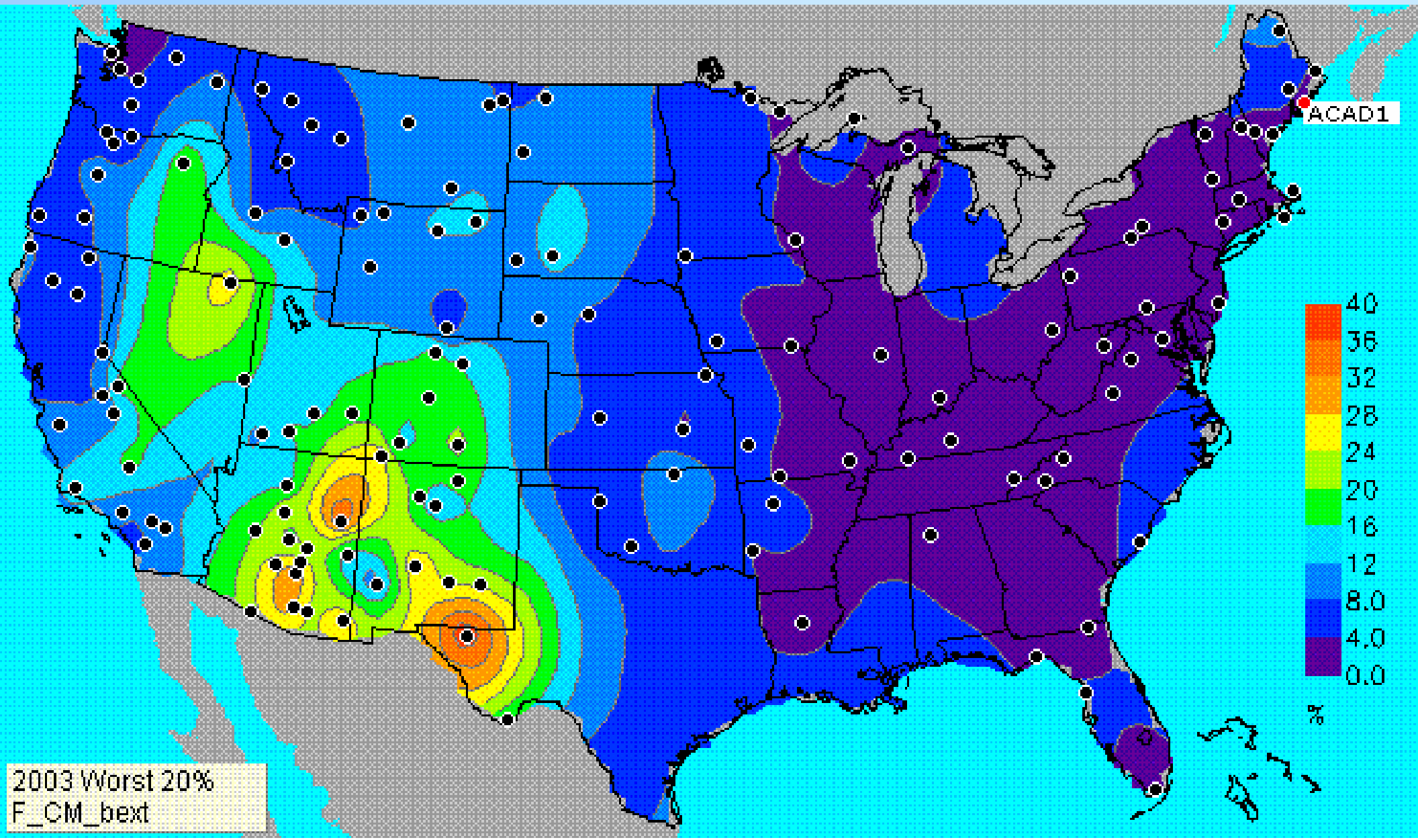
Percent of Visibility Impairment due to Course Mass on Worst 20% of Monitored Days



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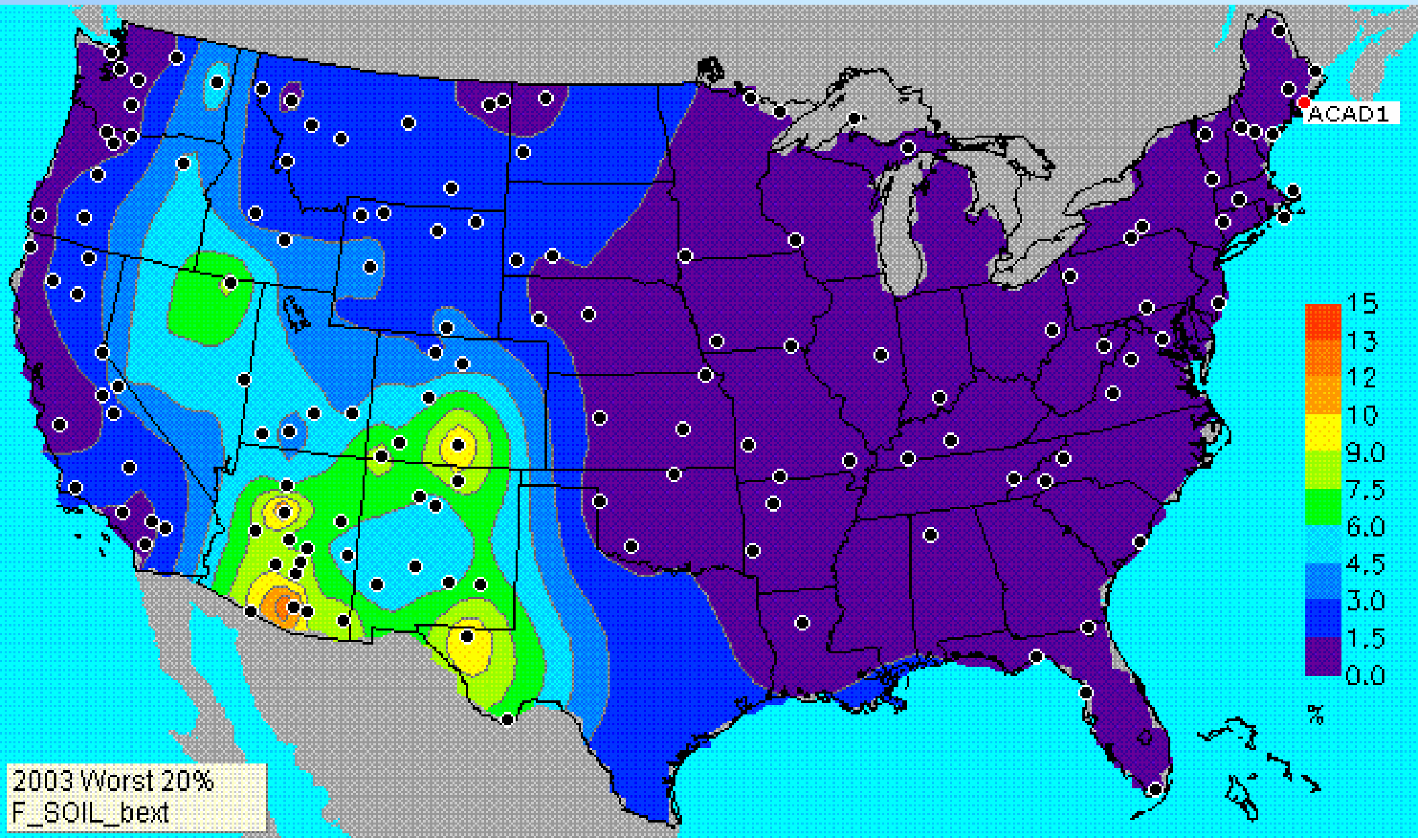
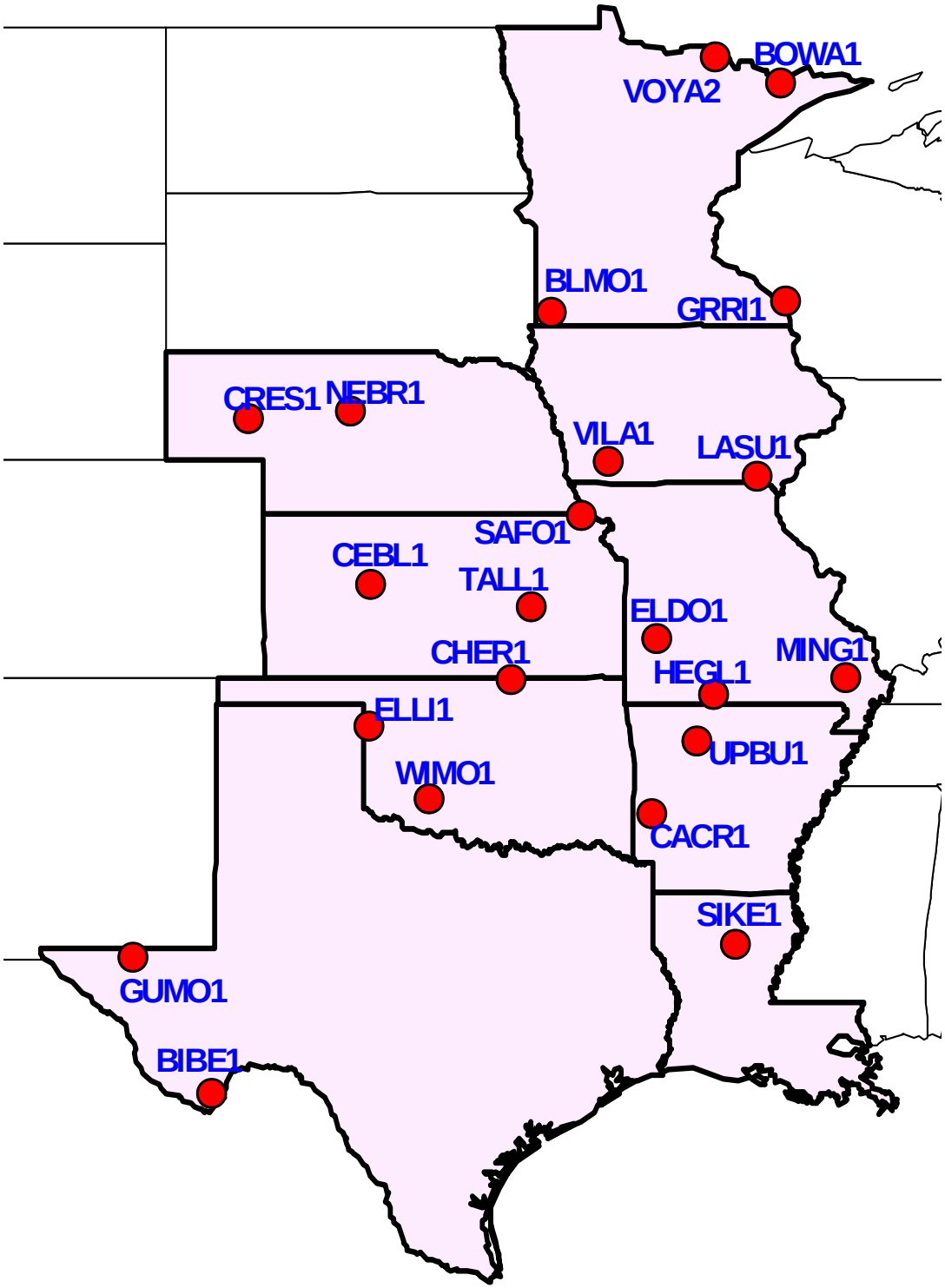
Percent of Visibility Impairment due to Fine Soil on Worst 20% of Monitored Days



Composition of Haze at CENRAP Visibility Sites

(Click on a site to see the composition pie chart)



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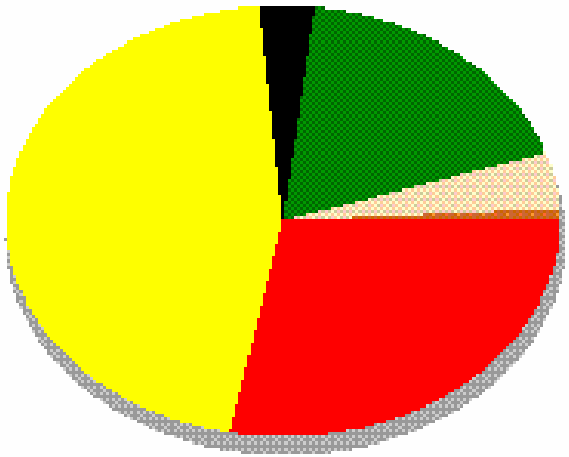
Northern Minnesota Aerosol Extinction Composition on 20% Worst Days in 2003

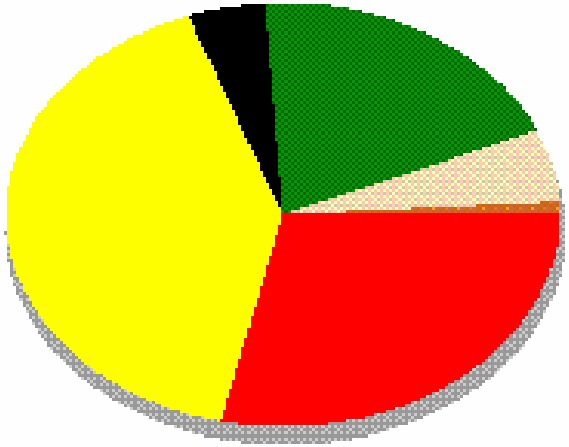
BOWA1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	19.1 Mm-1	28.9 %
ammSO4f_bext	29.2 Mm-1	44.3 %
ECf_bext	2.72 Mm-1	4.1 %
OMCf_bext	12.3 Mm-1	18.6 %
CM_bext	2.20 Mm-1	3.3 %
SOILf_bext	0.47 Mm-1	0.7 %

Total: 66.0 Mm-1

VOYA2 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	18.2 Mm-1	29.6 %
ammSO4f_bext	23.7 Mm-1	38.5 %
ECf_bext	3.47 Mm-1	5.6 %
OMCf_bext	13.0 Mm-1	21.1 %
CM_bext	2.74 Mm-1	4.4 %
SOILf_bext	0.47 Mm-1	0.8 %

Total: 61.6 Mm-1

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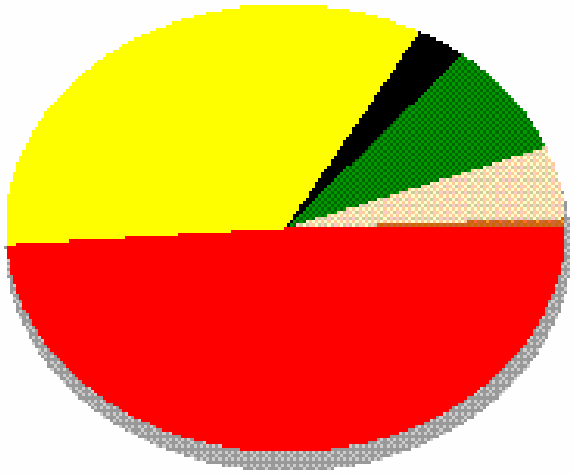
Southern Minnesota Aerosol Extinction Composition on 20% Worst Days in 2003

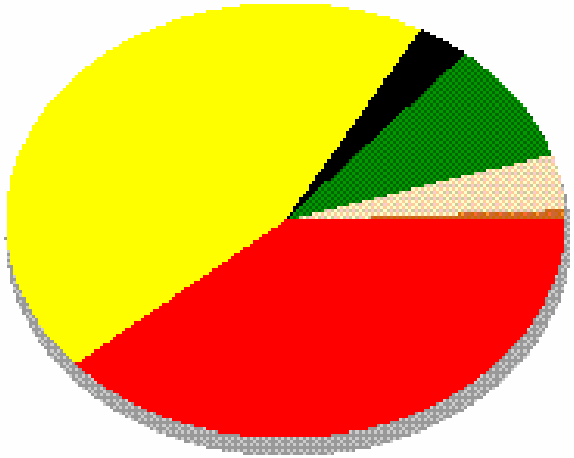
BLMO1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	62.3 Mm-1	49.1 %
ammSO4f_bext	45.3 Mm-1	35.7 %
ECf_bext	3.98 Mm-1	3.1 %
OMCf_bext	9.44 Mm-1	7.4 %
CM_bext	5.24 Mm-1	4.1 %
SOILf_bext	0.69 Mm-1	0.5 %

Total: 126.9 Mm-1

GRRI1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	56.8 Mm-1	40.5 %
ammSO4f_bext	62.3 Mm-1	44.4 %
ECf_bext	4.64 Mm-1	3.3 %
OMCf_bext	11.3 Mm-1	8.0 %
CM_bext	4.59 Mm-1	3.3 %
SOILf_bext	0.81 Mm-1	0.6 %

Total: 140.4 Mm-1

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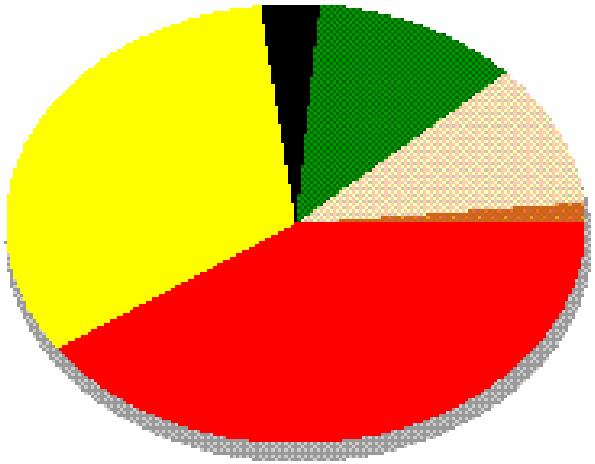
Nebraska Aerosol Extinction Composition on 20% Worst Days in 2003

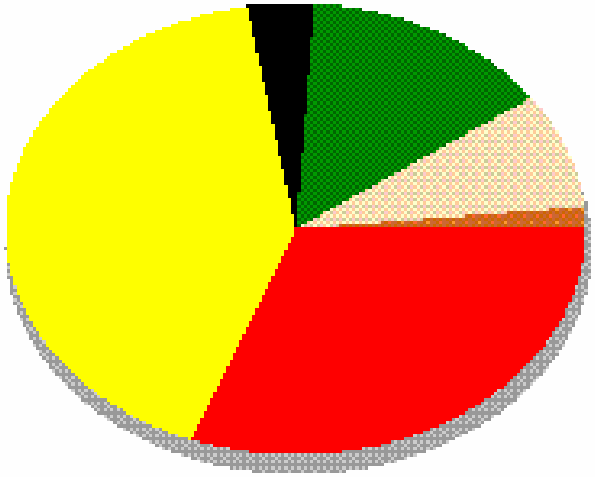
CRES1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	24.6 Mm-1	42.1 %
ammSO4f_bext	17.7 Mm-1	30.3 %
ECf_bext	2.45 Mm-1	4.2 %
OMCf_bext	7.72 Mm-1	13.2 %
CM_bext	5.19 Mm-1	8.9 %
SOILf_bext	0.70 Mm-1	1.2 %

Total: 58.4 Mm-1

NEBR1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	22.9 Mm-1	32.3 %
ammSO4f_bext	27.8 Mm-1	39.3 %
ECf_bext	3.36 Mm-1	4.7 %
OMCf_bext	11.0 Mm-1	15.6 %
CM_bext	4.88 Mm-1	6.9 %
SOILf_bext	0.86 Mm-1	1.2 %

Total: 70.8 Mm-1

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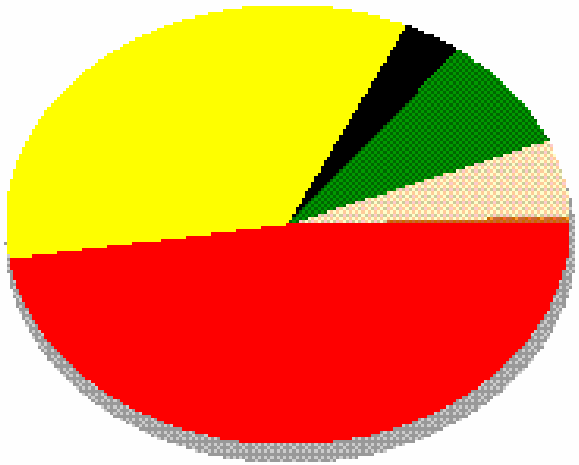
Iowa Aerosol Extinction Composition on 20% Worst Days in 2003

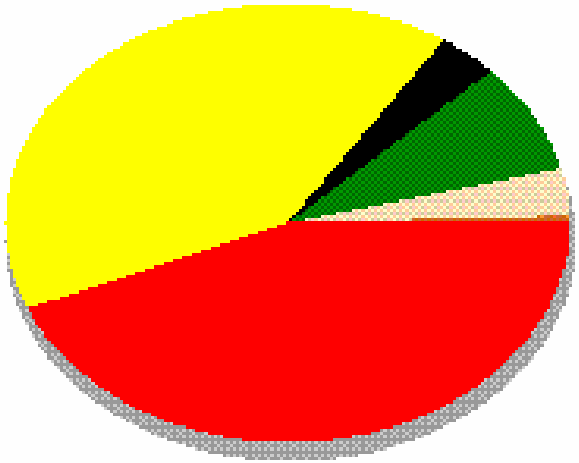
VILA1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	63.4 Mm-1	48.1 %
ammSO4f_bext	46.8 Mm-1	35.5 %
ECf_bext	4.91 Mm-1	3.7 %
OMCf_bext	10.2 Mm-1	7.8 %
CM_bext	5.85 Mm-1	4.4 %
SOILf_bext	0.66 Mm-1	0.5 %

Total: 131.8 Mm-1

LASU1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	65.6 Mm-1	45.0 %
ammSO4f_bext	60.2 Mm-1	41.3 %
ECf_bext	5.20 Mm-1	3.6 %
OMCf_bext	10.4 Mm-1	7.1 %
CM_bext	3.95 Mm-1	2.7 %
SOILf_bext	0.58 Mm-1	0.4 %

Total: 145.9 Mm-1

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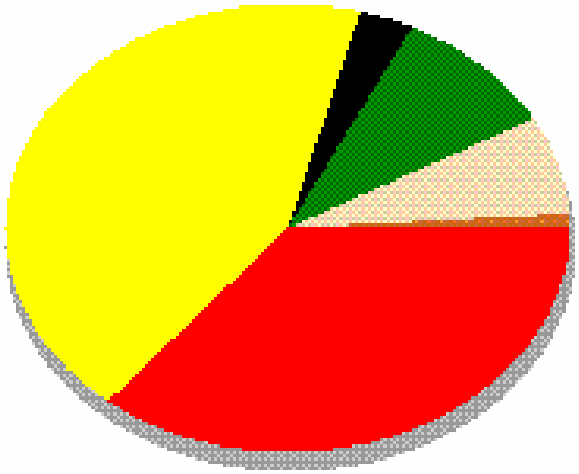
Kansas Aerosol Extinction Composition on 20% Worst Days in 2003

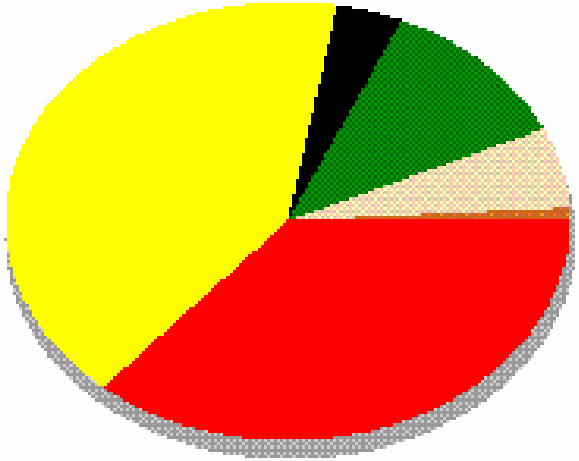
CEBL1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	36.2 Mm-1	38.0 %
ammSO4f_bext	40.3 Mm-1	42.3 %
ECf_bext	3.52 Mm-1	3.7 %
OMCf_bext	9.05 Mm-1	9.5 %
CM_bext	5.49 Mm-1	5.8 %
SOILf_bext	0.76 Mm-1	0.8 %

Total: 95.4 Mm-1

SAFO1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	47.0 Mm-1	38.3 %
ammSO4f_bext	49.4 Mm-1	40.3 %
ECf_bext	5.65 Mm-1	4.6 %
OMCf_bext	13.8 Mm-1	11.3 %
CM_bext	5.82 Mm-1	4.7 %
SOILf_bext	0.93 Mm-1	0.8 %

Total: 122.7 Mm-1

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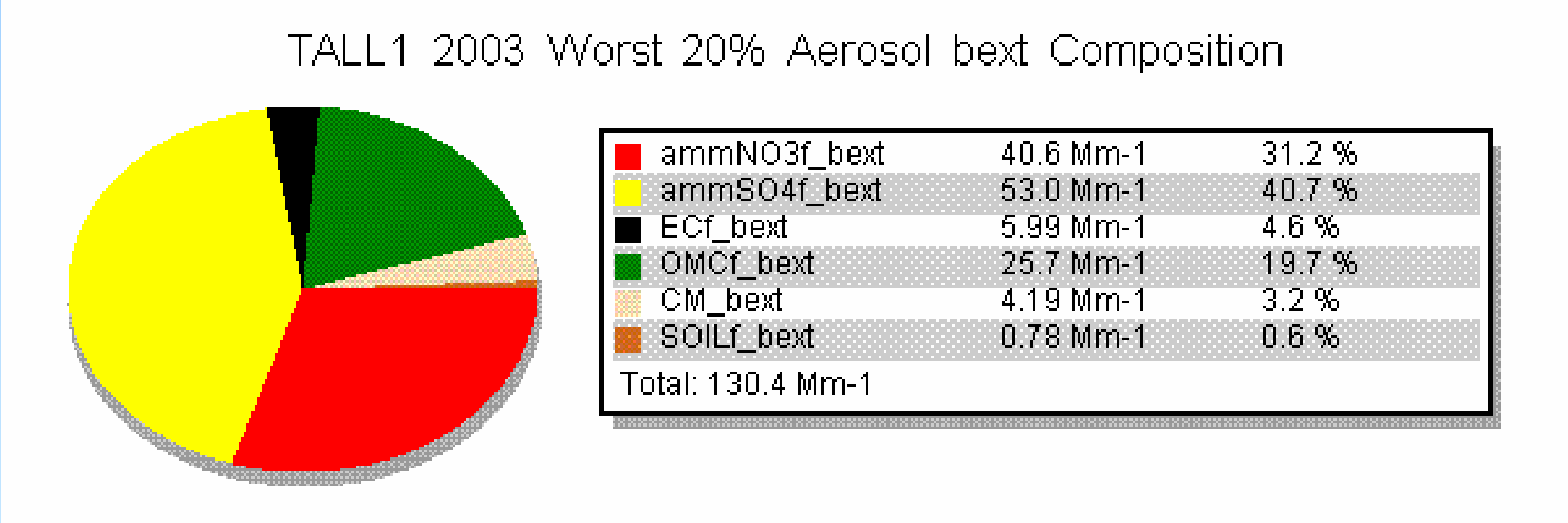
Kansas Aerosol Extinction Composition on 20% Worst Days in 2003



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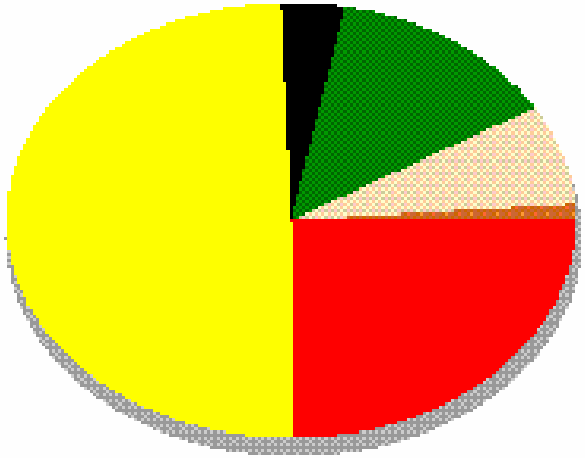
Missouri Aerosol Extinction Composition on 20% Worst Days in 2003

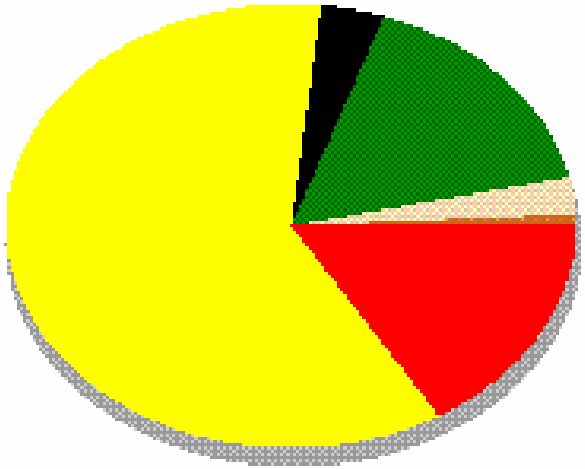
ELDO1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	34.5 Mm-1	24.9 %
ammSO4f_bext	68.4 Mm-1	49.4 %
ECf_bext	6.30 Mm-1	4.5 %
OMCf_bext	19.6 Mm-1	14.2 %
CM_bext	8.40 Mm-1	6.1 %
SOILf_bext	1.28 Mm-1	0.9 %

Total: 138.4 Mm-1

HEGL1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	17.4 Mm-1	14.5 %
ammSO4f_bext	75.5 Mm-1	62.7 %
ECf_bext	5.43 Mm-1	4.5 %
OMCf_bext	18.8 Mm-1	15.6 %
CM_bext	2.53 Mm-1	2.1 %
SOILf_bext	0.80 Mm-1	0.7 %

Total: 120.5 Mm-1

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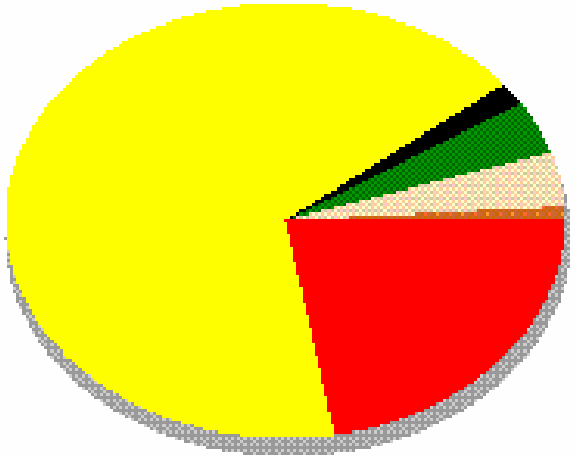
Missouri Aerosol Extinction Composition on 20% Worst Days in 2003



ammNO3f_bext	28.9 Mm-1	21.4 %
ammSO4f_bext	94.1 Mm-1	69.7 %
ECf_bext	2.11 Mm-1	1.6 %
OMCf_bext	4.49 Mm-1	3.3 %
CM_bext	4.33 Mm-1	3.2 %
SOILf_bext	1.06 Mm-1	0.8 %

Total: 135.0 Mm-1

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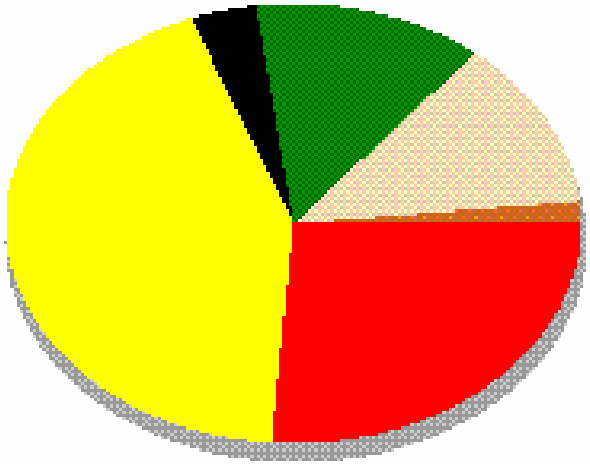
Oklahoma Aerosol Extinction Composition on 20% Worst Days in 2003

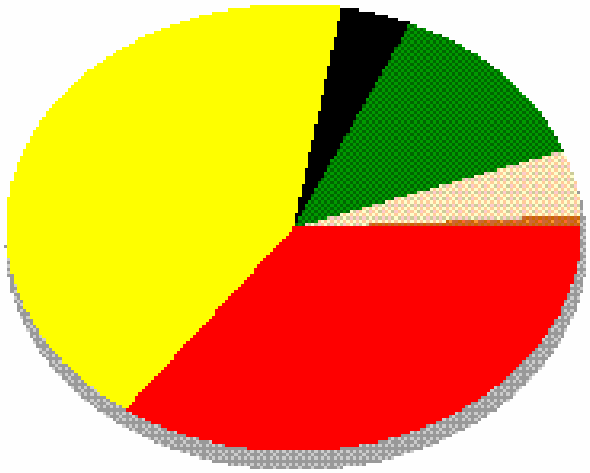
CHER1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	31.3 Mm-1	26.6 %
ammSO4f_bext	48.3 Mm-1	41.1 %
ECf_bext	5.38 Mm-1	4.6 %
OMCf_bext	18.3 Mm-1	15.6 %
CM_bext	12.8 Mm-1	10.9 %
SOILf_bext	1.48 Mm-1	1.3 %

Total: 117.5 Mm-1

ELLI1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	31.1 Mm-1	36.9 %
ammSO4f_bext	35.1 Mm-1	41.5 %
ECf_bext	4.10 Mm-1	4.9 %
OMCf_bext	10.4 Mm-1	12.3 %
CM_bext	3.17 Mm-1	3.8 %
SOILf_bext	0.56 Mm-1	0.7 %

Total: 84.4 Mm-1

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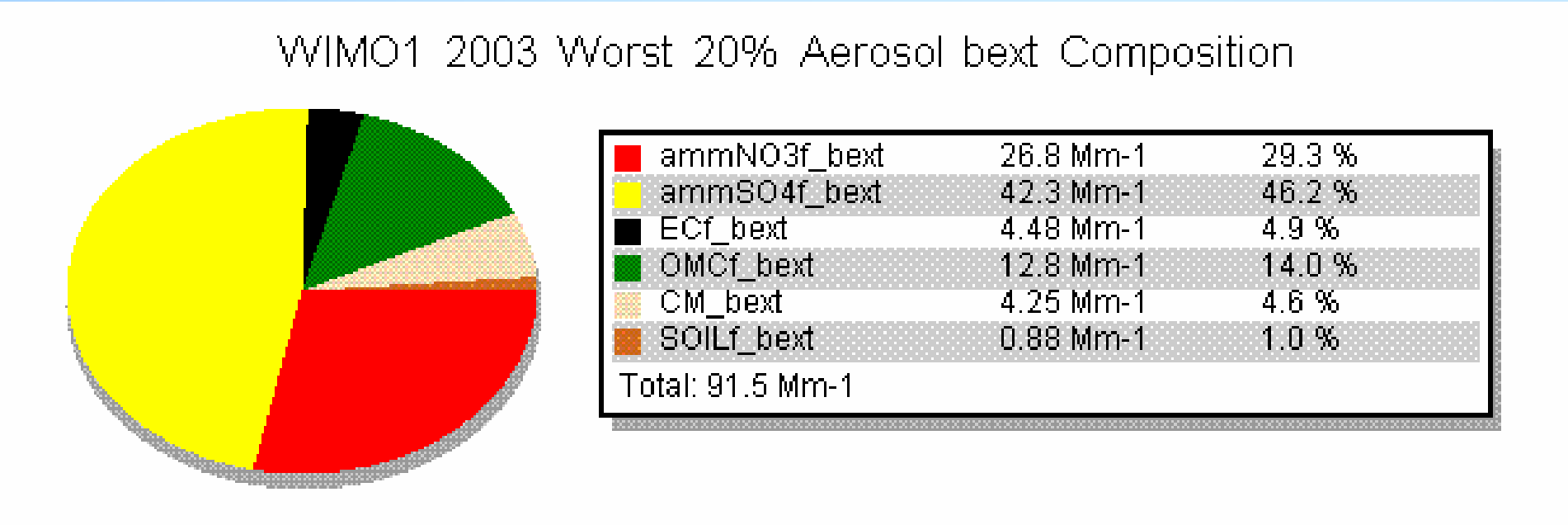
Oklahoma Aerosol Extinction Composition on 20% Worst Days in 2003



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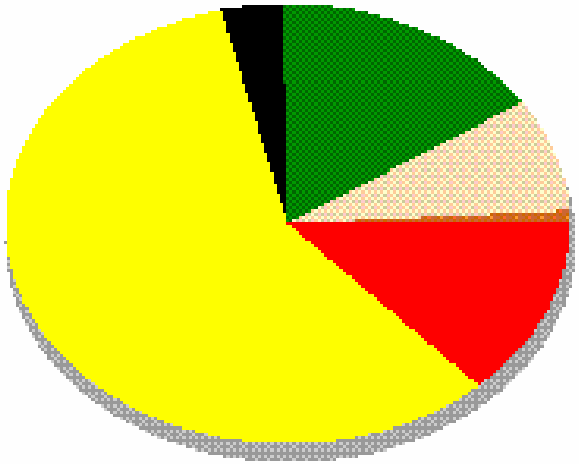
Arkansas Aerosol Extinction Composition on 20% Worst Days in 2003

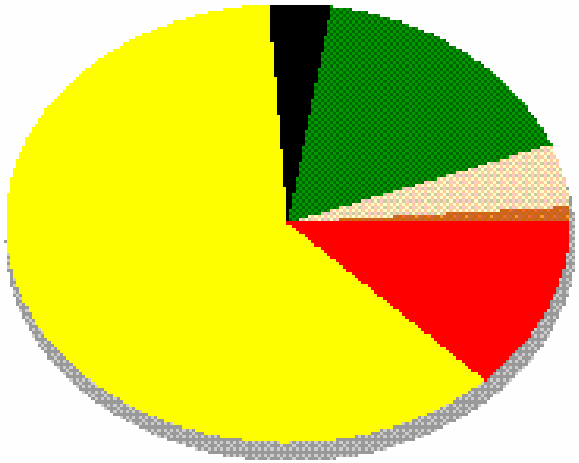
UPBU1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	14.1 Mm-1	11.2 %
ammSO4f_bext	74.6 Mm-1	59.0 %
ECf_bext	5.62 Mm-1	4.4 %
OMCf_bext	22.5 Mm-1	17.8 %
CM_bext	8.65 Mm-1	6.8 %
SOILf_bext	0.94 Mm-1	0.7 %

Total: 126.5 Mm-1

CACR1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	13.2 Mm-1	10.7 %
ammSO4f_bext	77.1 Mm-1	62.9 %
ECf_bext	5.57 Mm-1	4.5 %
OMCf_bext	21.1 Mm-1	17.2 %
CM_bext	4.49 Mm-1	3.7 %
SOILf_bext	1.15 Mm-1	0.9 %

Total: 122.6 Mm-1

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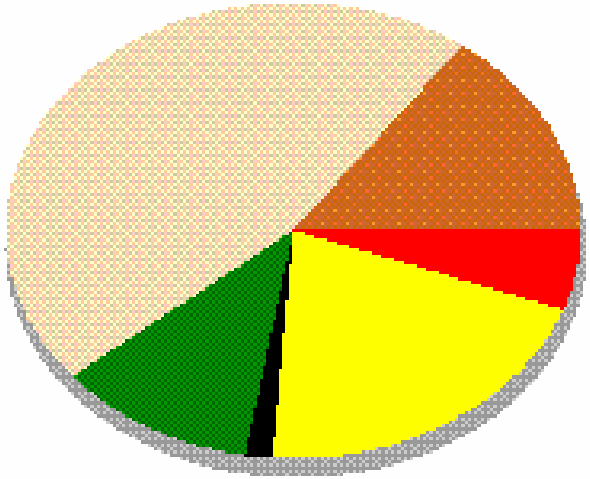
Texas Aerosol Extinction Composition on 20% Worst Days in 2003

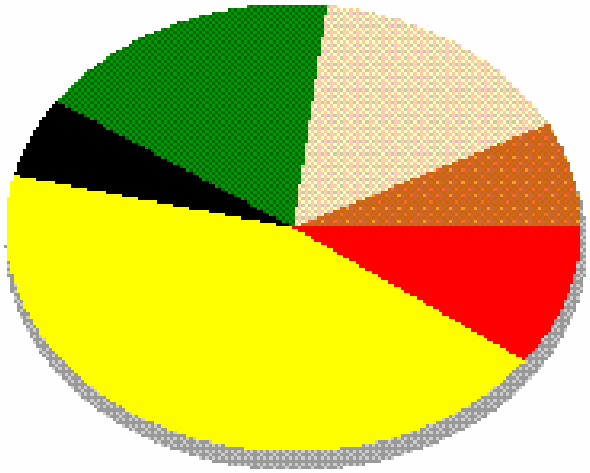
GUMO1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	2.75 Mm-1	4.5 %
ammSO4f_bext	13.6 Mm-1	22.0 %
ECf_bext	1.19 Mm-1	1.9 %
OMCf_bext	7.64 Mm-1	12.4 %
CM_bext	28.4 Mm-1	46.1 %
SOILf_bext	8.04 Mm-1	13.1 %

Total: 61.5 Mm-1

BIBE1 2003 Worst 20% Aerosol bext Composition



ammNO3f_bext	3.76 Mm-1	8.3 %
ammSO4f_bext	20.2 Mm-1	44.7 %
ECf_bext	2.20 Mm-1	4.9 %
OMCf_bext	8.86 Mm-1	19.6 %
CM_bext	7.46 Mm-1	16.5 %
SOILf_bext	2.79 Mm-1	6.2 %

Total: 45.3 Mm-1

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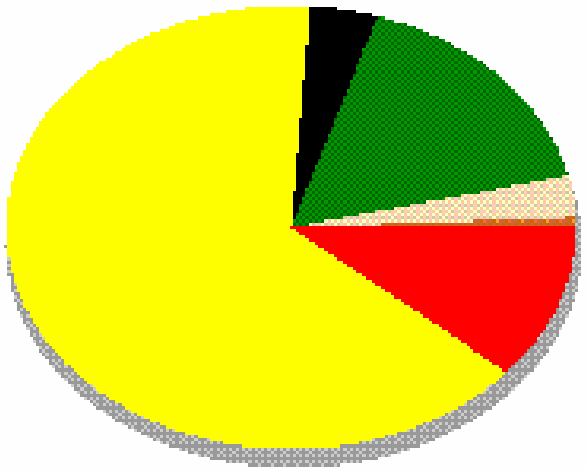
Louisiana Aerosol Extinction Composition on 20% Worst Days in 2003



ammNO3f_bext	12.1 Mm-1	9.4 %
ammSO4f_bext	86.0 Mm-1	66.9 %
ECf_bext	6.21 Mm-1	4.8 %
OMCf_bext	20.4 Mm-1	15.9 %
CM_bext	3.06 Mm-1	2.4 %
SOILf_bext	0.71 Mm-1	0.6 %

Total: 128.4 Mm-1

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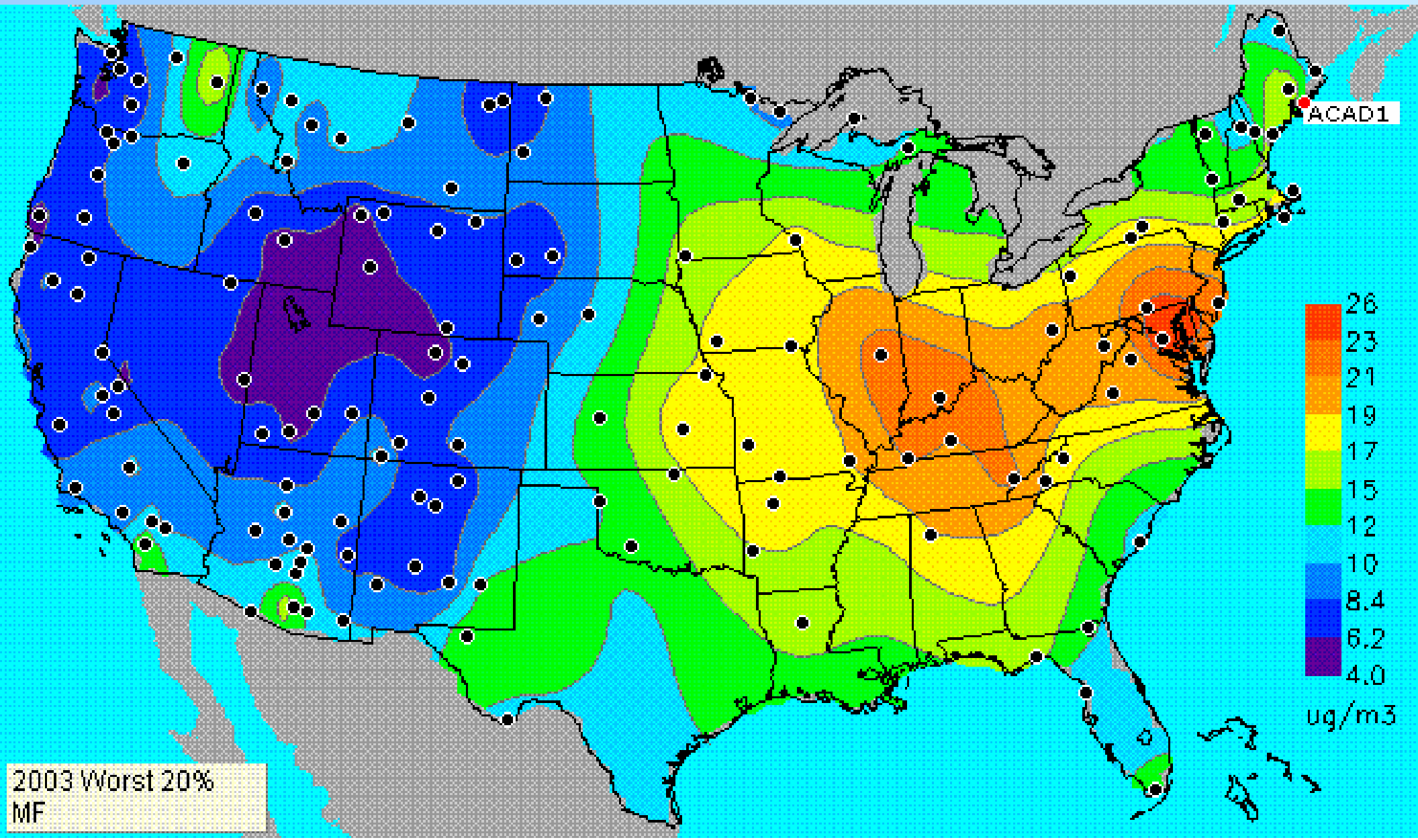
Fine Mass Concentration on Worst 20% of Monitored Days



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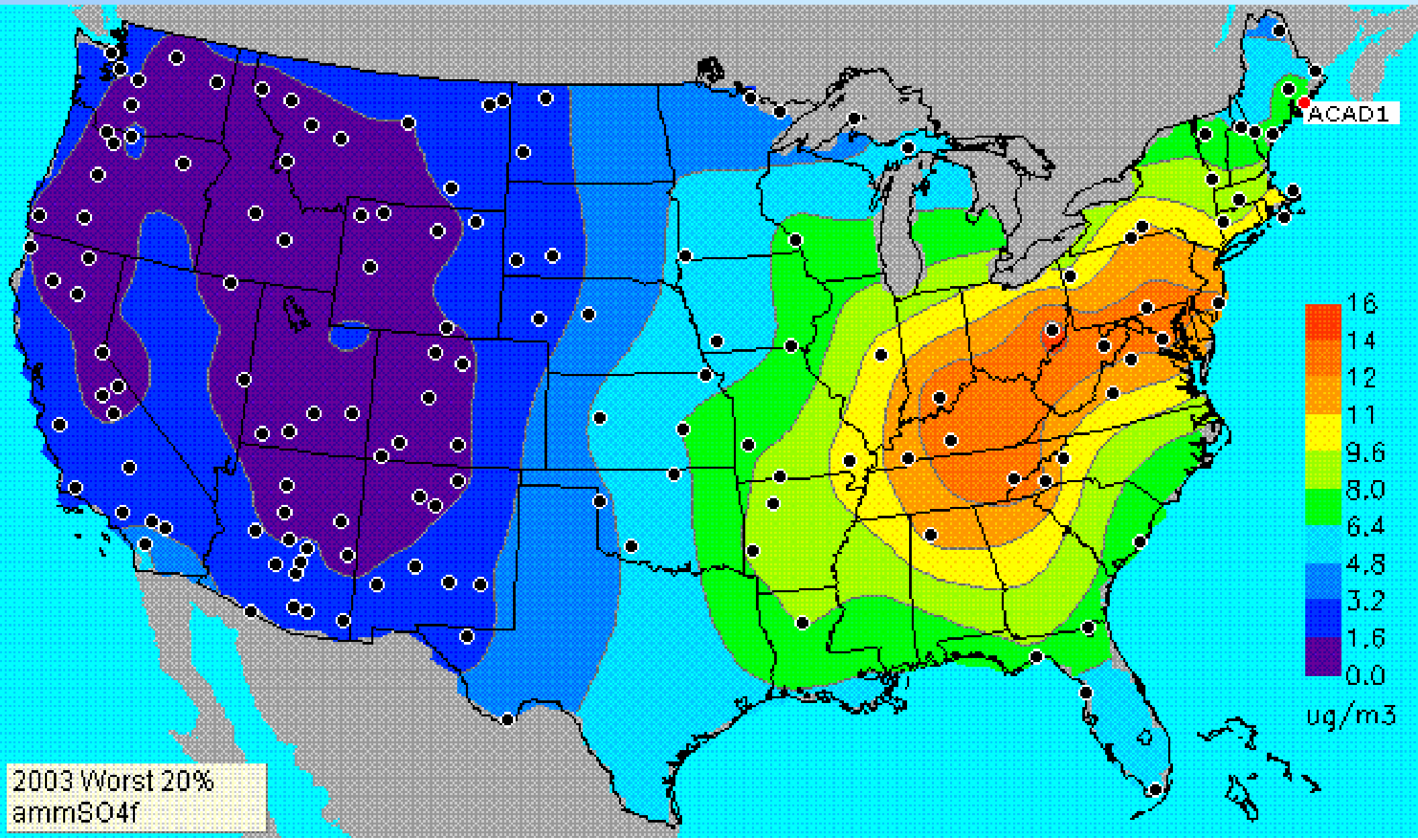
Ammonium Sulfate Concentration on Worst 20% of Monitored Days



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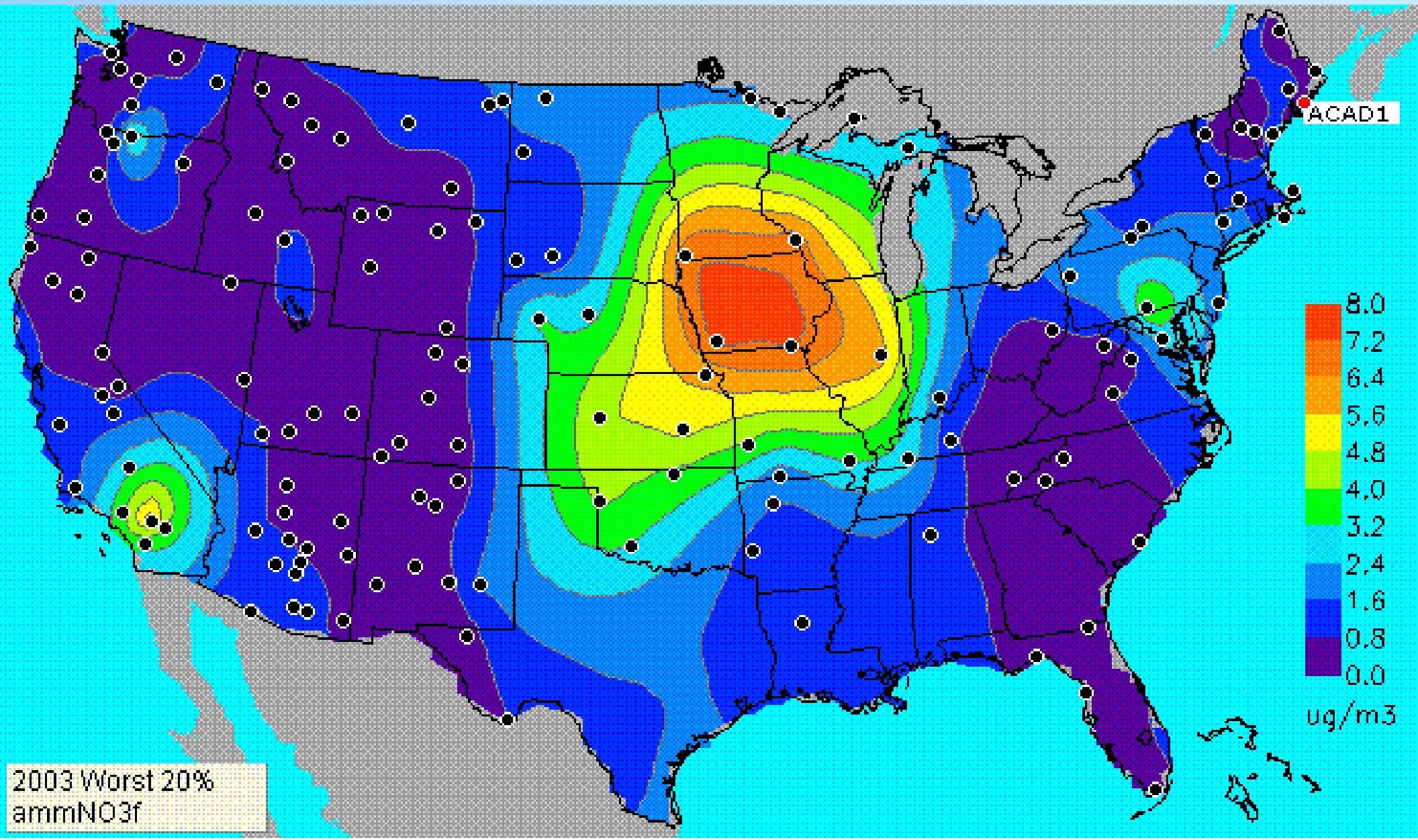
Ammonium Nitrate Concentration on Worst 20% of Monitored Days



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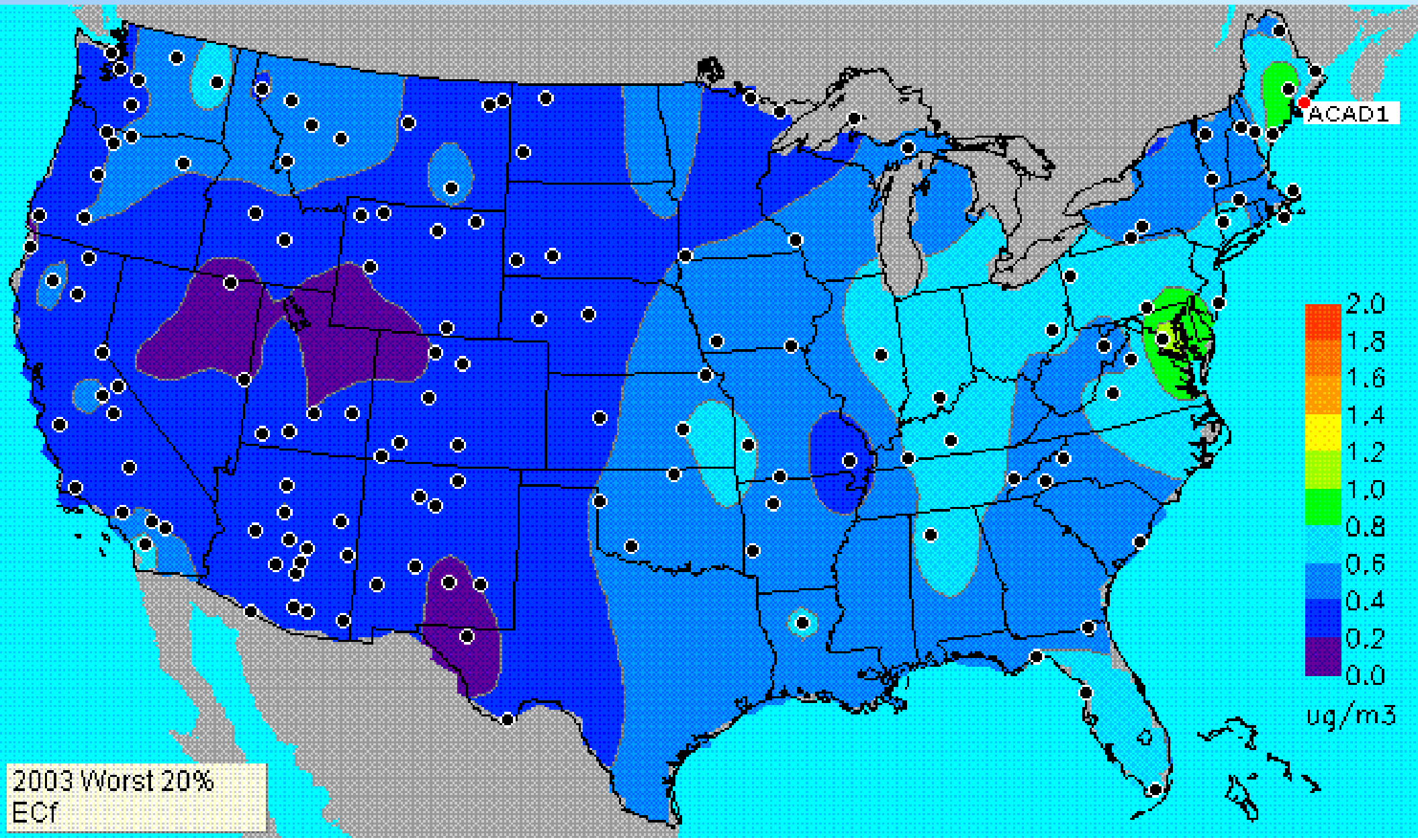
Elemental Carbon Concentration on Worst 20% of Monitored Days



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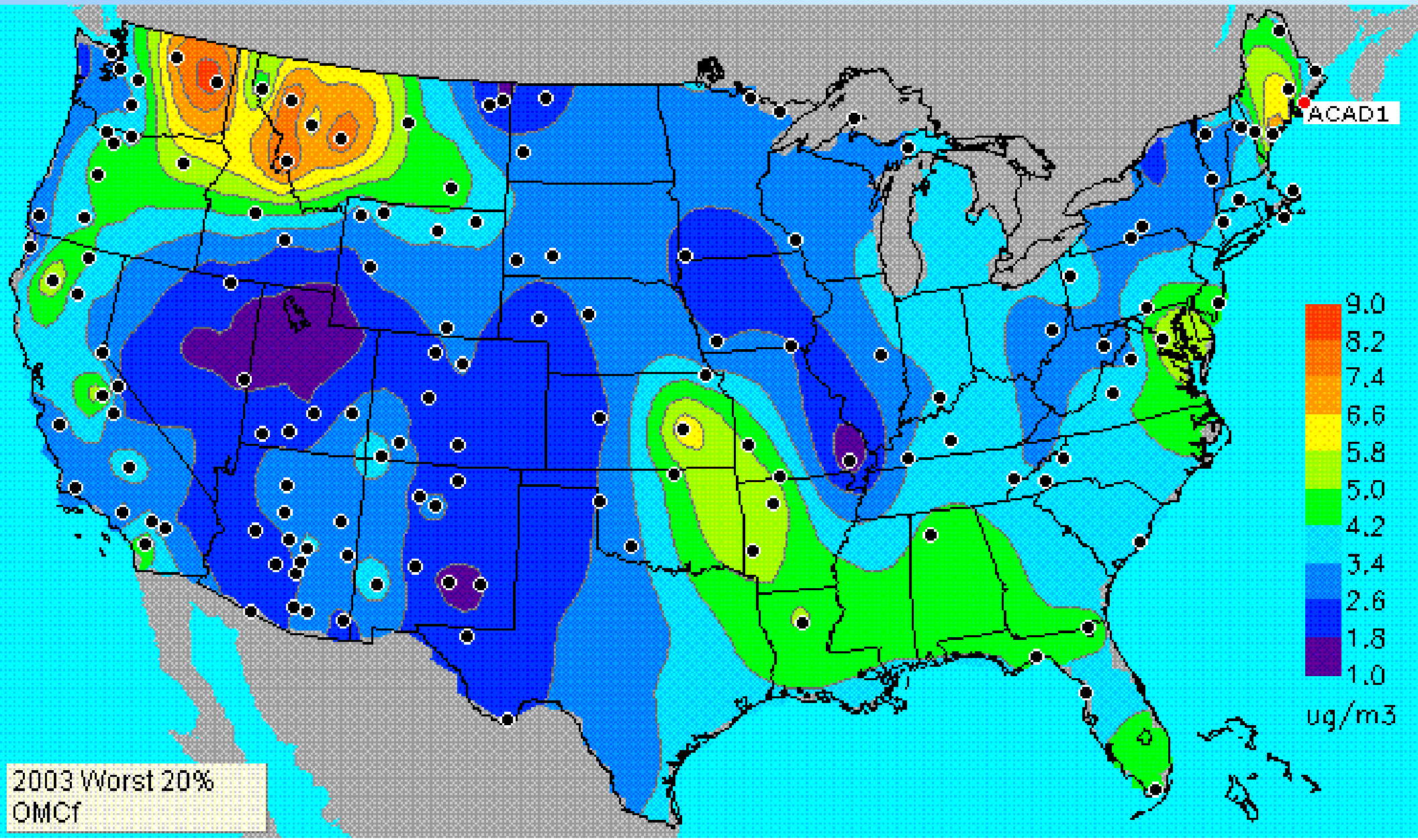
Organic Carbon Concentration on Worst 20% of Monitored Days



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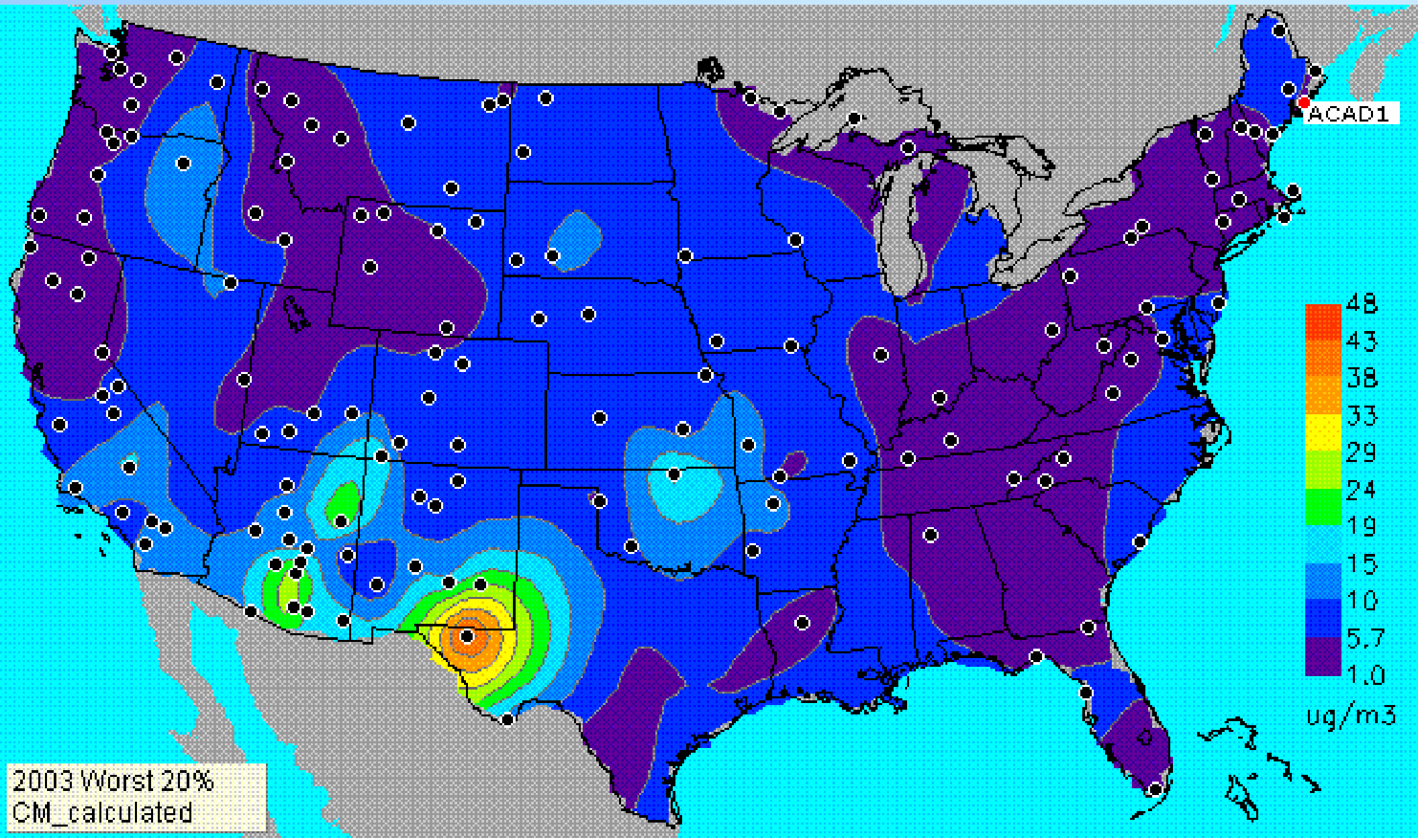
Course Mass Concentration on Worst 20% of Monitored Days



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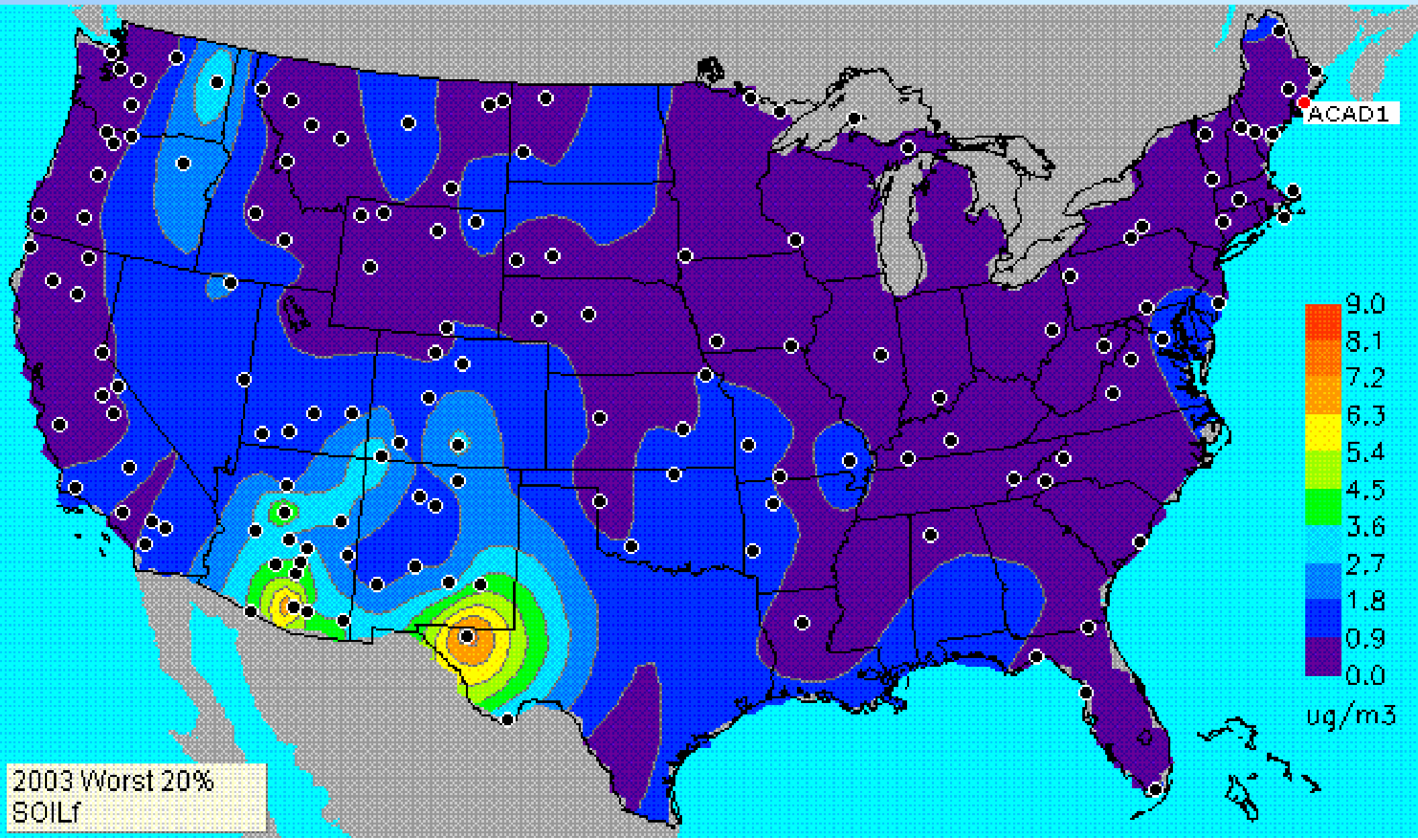
Fine Soil Concentration on Worst 20% of Monitored Days



Internet Visibility Resources:

IMPROVE Website

http://vista.cira.colostate.edu/improve/Default.htm

VIEWS Graphic Viewer

http://vista.cira.colostate.edu/views/

EPA AirData Website

http://www.epa.gov/air/data/index.html