Environment Canada Environnement Canada

Canada

Visibility Modeling in the Lower Fraser Valley, B.C..

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British Columbia Visibility Coordinating Committee

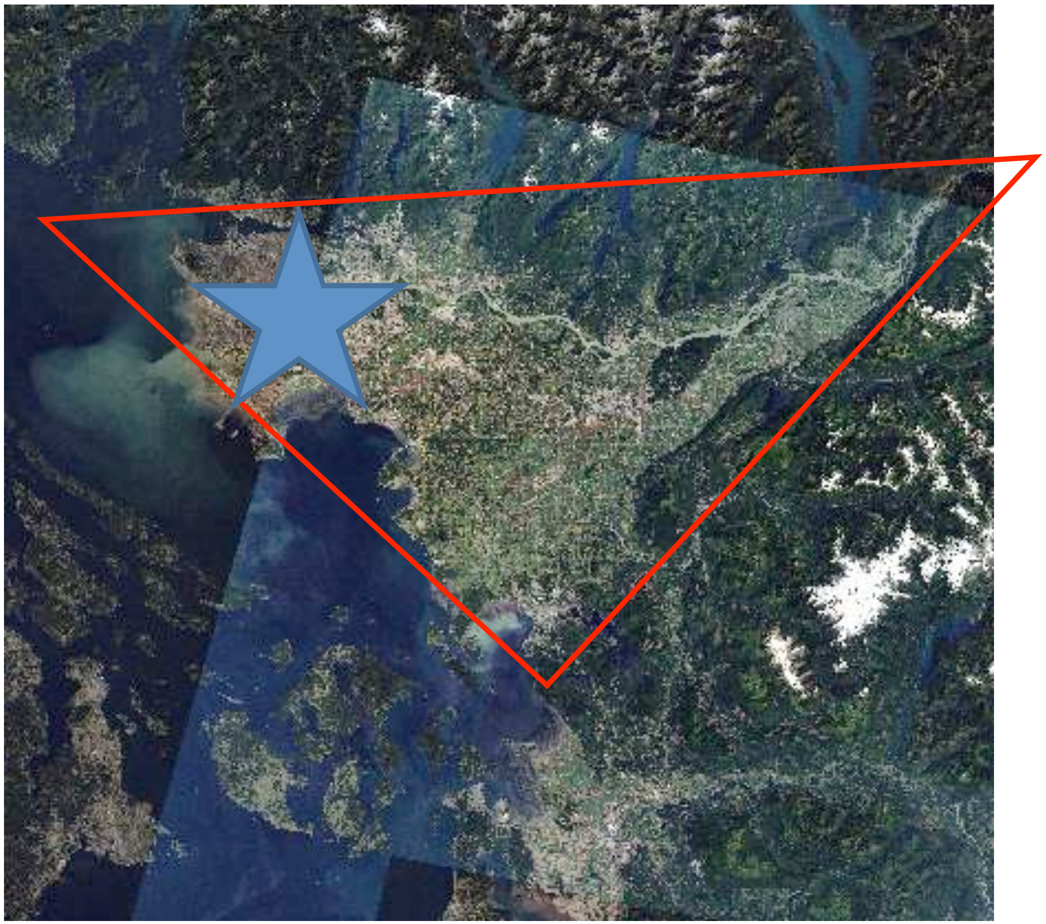
- BCVCC: Inter-agency committee of Regional, Provincial and Federal agencies.

Metro Vancouver

Fraser Valley Regional District

- Four BCVCC workgroups undertake various projects
    - **Science** – monitoring, modelling and data analysis
    - **Goal and Index**
    - **Business Case**
    - **Strategic Outreach** – communications, website

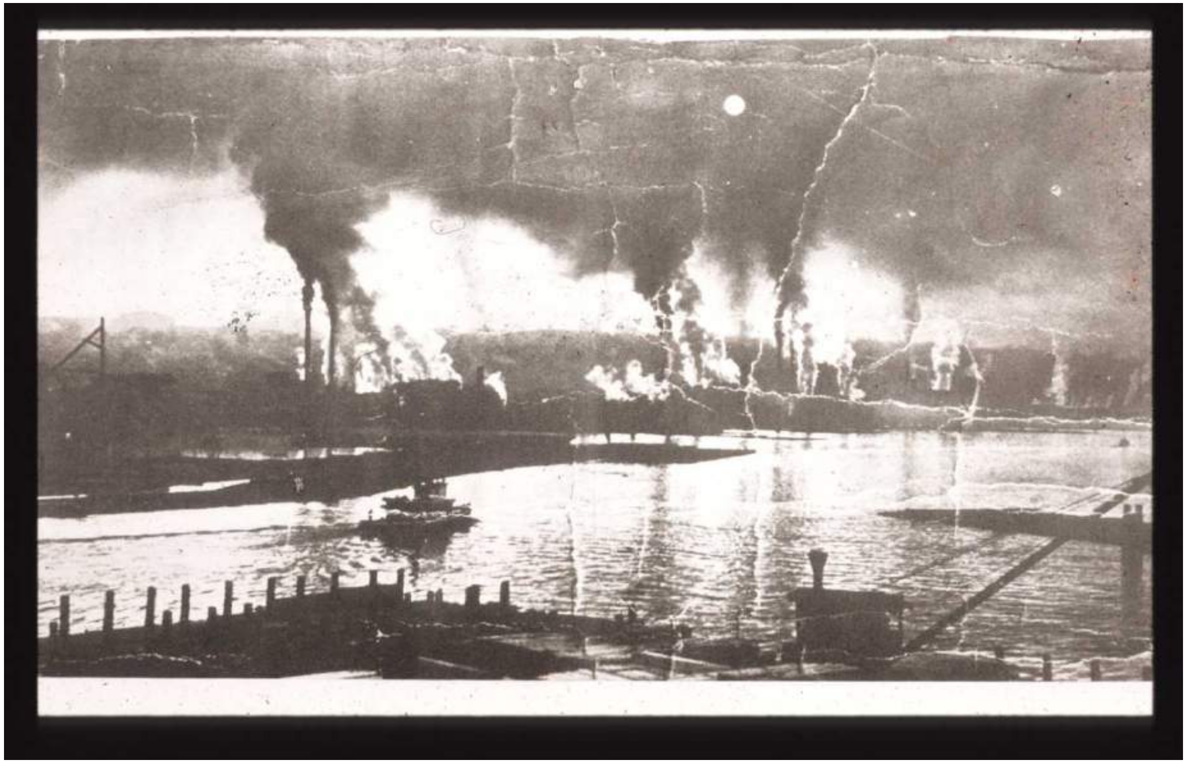
Setting: LFV



- Triangular valley
- ~2 million people mainly in Vancouver and its suburbs

Background

- Over the past century, LFV has largely de-industrialized.
- This has had profound changes in the region's air quality.
- Going from a problem of SO2 and smoke …



False Creek, early 1900s. Plumes from lumber mills.

Regional Haze – July 2012

Why Address Visibility?

- In 2011, Metro Vancouver adopted Integrated Air Quality and Greenhouse Gas Management Plan (IAQGGMP):
  - → Goal 1: Protect human health and the environment
  - →**Goal 2: Improve visual air quality**
  - →Goal 3: Minimize region's contribution to climate change

How to Address Visibility?

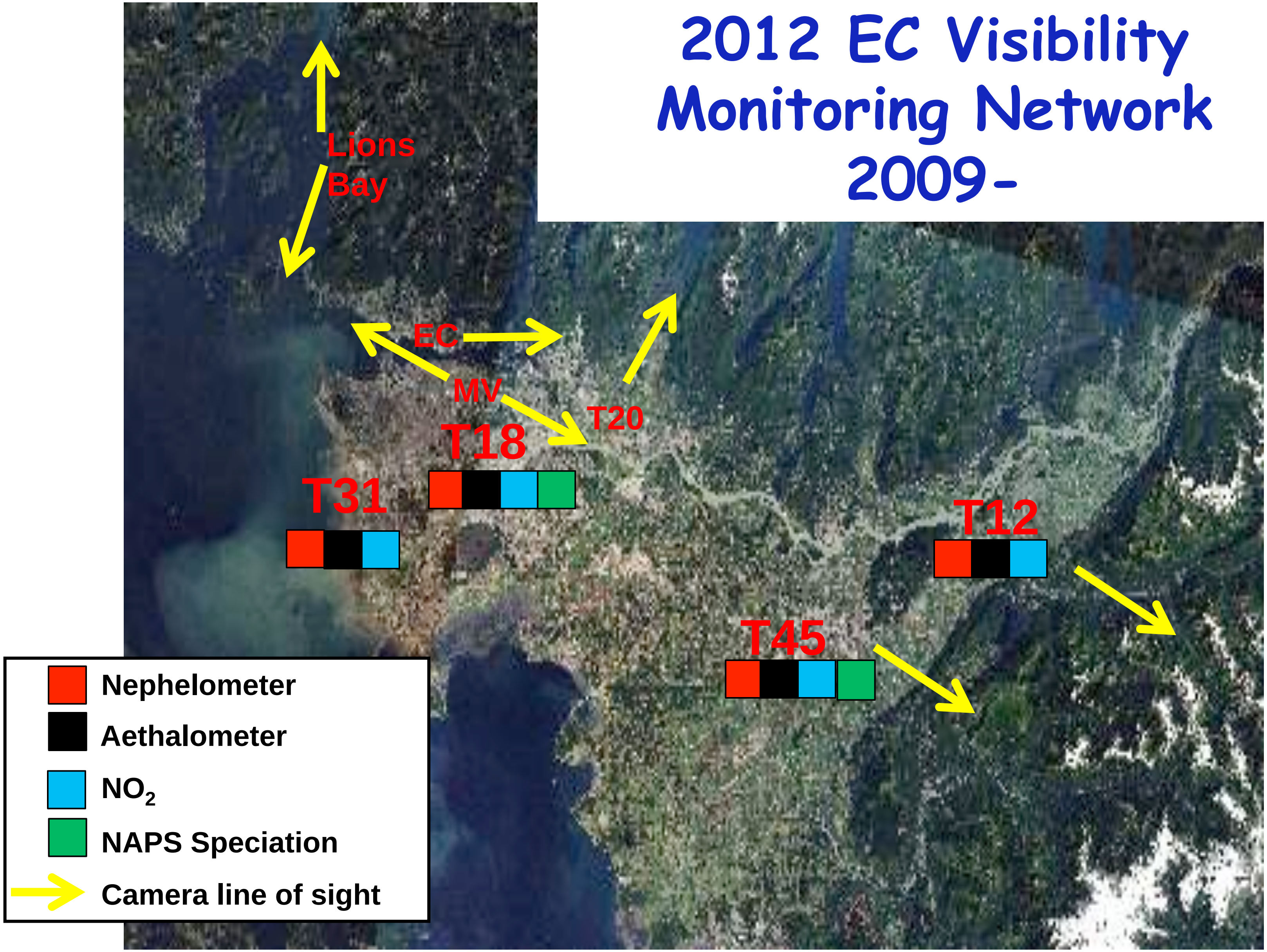
1. Management
2. Measurement
3. Modeling

Visibility Measurement

	Absorption	Scattering
Gas	Bag: mainly due to NO_2	Bsg: Rayleigh scattering
Particulates	Bap: measured with Aethalometer	Bsp: measured with Nephelometer

$$Bext = Bag + Bsg + Bap + Bsp$$

2012 EC Visibility Monitoring Network 2009-



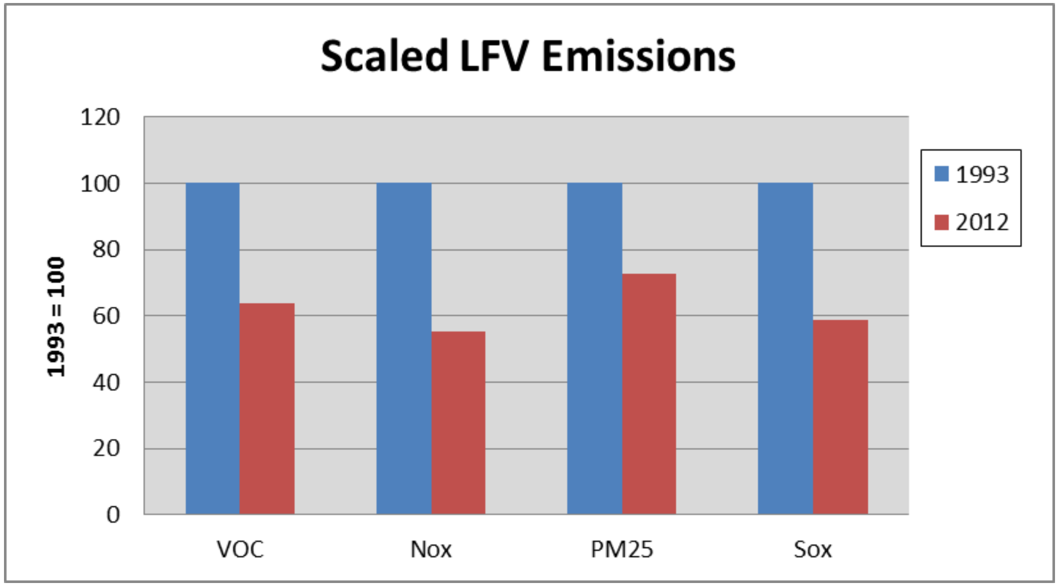
Visibility Modeling

- Use photochemical transport model to simulate visibility degradation due to local emissions
- Use model to find which pollutant sources/acitivites contribute most to visibility impairment
- Perform policy modeling using emission scenarios
- Model Evaluation over historic episodes

Exercising the Model

- Model needs to accurately represent response of airshed to potentially large (~50%) emissions reductions
- Test model's behaviour across similar emission changes by looking at events in 1993 and 2012

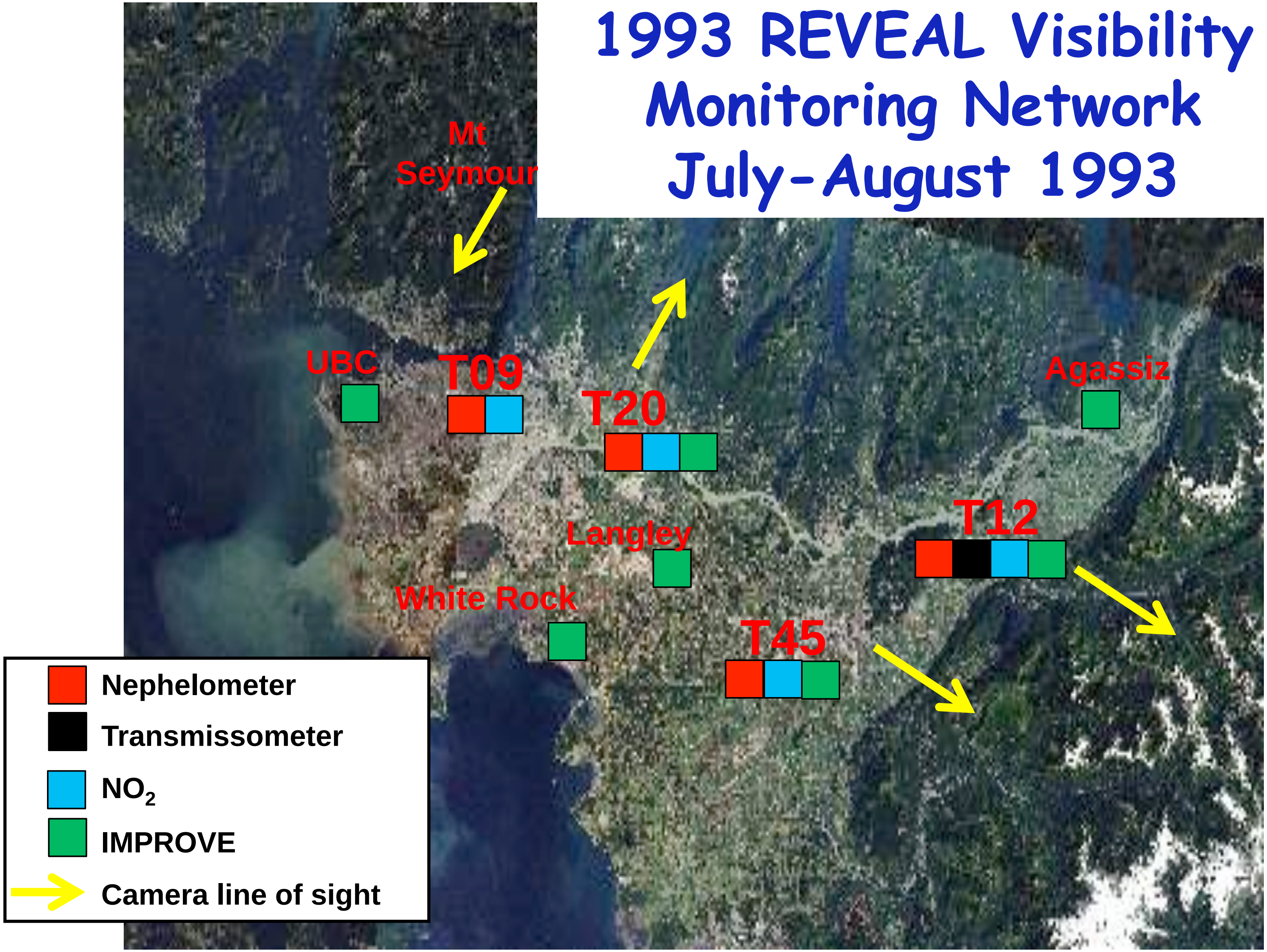
Since early 1990's LFV undergone sizeable emission reductions



REVEAL

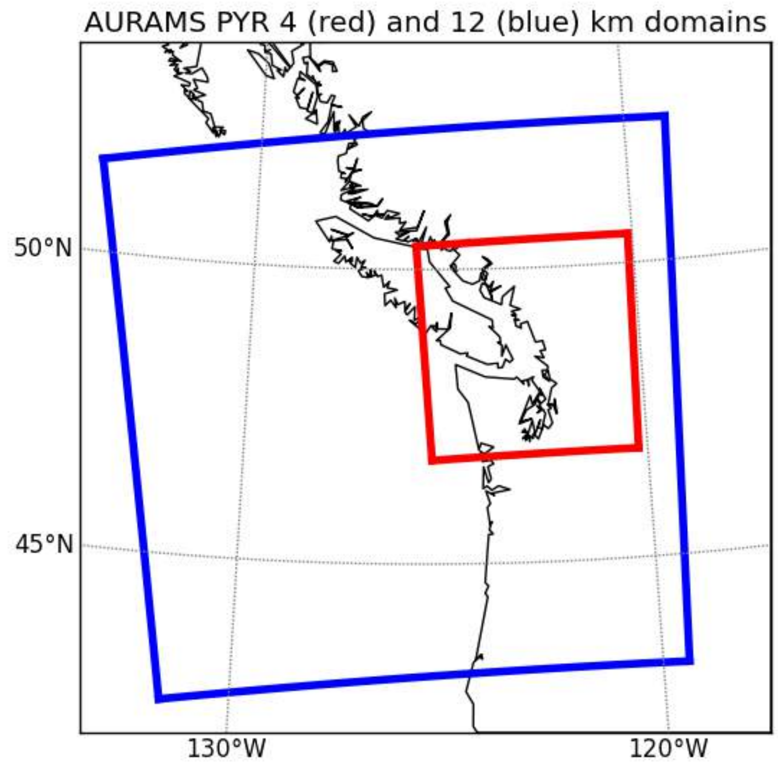
- During July-August 1993 extensive field campaign to measure visibility in the LFV
- REVEAL (Regional Visibility Experimental Assessment in the LFV)
- Hourly measurements of bext, bsp
- Cameras, speciated PM25
- Sites at Pitt Meadows, Abbotsford and Chilliwack
- Part of bigger Pacific '93 field campaign

1993 REVEAL Visibility Monitoring Network July-August 1993



Model Evaluation Strategy

- Use EC's AURAMS model
- Nested domain down to 4km resolution
- Particle physics and chemistry handled with 12 size bin particle speciation
- Emissions from SMOKE using MV backcast and forecast emission levels
- Model event during REVEAL 1993 field campaign and Summer 2012
- Assess model's ability to respond to large scale emission changes using all the measured extinction data



Calculating extinction from AURAMS

Use the 12 bins of speciated PM25 output to calculate extinction

(IMPROVE reconstruction: Pitchford et al., JAWMA,2007)

$$
\begin{aligned}
bsp \approx\ & 2.2\times f_S(RH)\times[\text{Small Sulfate}] + 4.8\times f_L(RH)\times[\text{Large Sulfate}] \\
& + 2.4\times f_S(RH)\times[\text{Small Nitrate}] + 5.1\times f_L(RH)\times[\text{Large Nitrate}] \\
& + 2.8\times[\text{Small Organic Mass}] + 6.1\times[\text{Large Organic Mass}]
\end{aligned}
$$

$$
\begin{aligned}
bap \approx\ & 10\times[Elemental\ Carbon] \\
& + 1\times[Fine\ Soil] \\
& + 1.7\times f_{SS}(RH)\times[\text{Sea Salt}] \\
& + 0.6\times[Coarse\ Mass]
\end{aligned}
$$

$$bsg = \text{Rayleigh Scattering (Site Specific)}$$

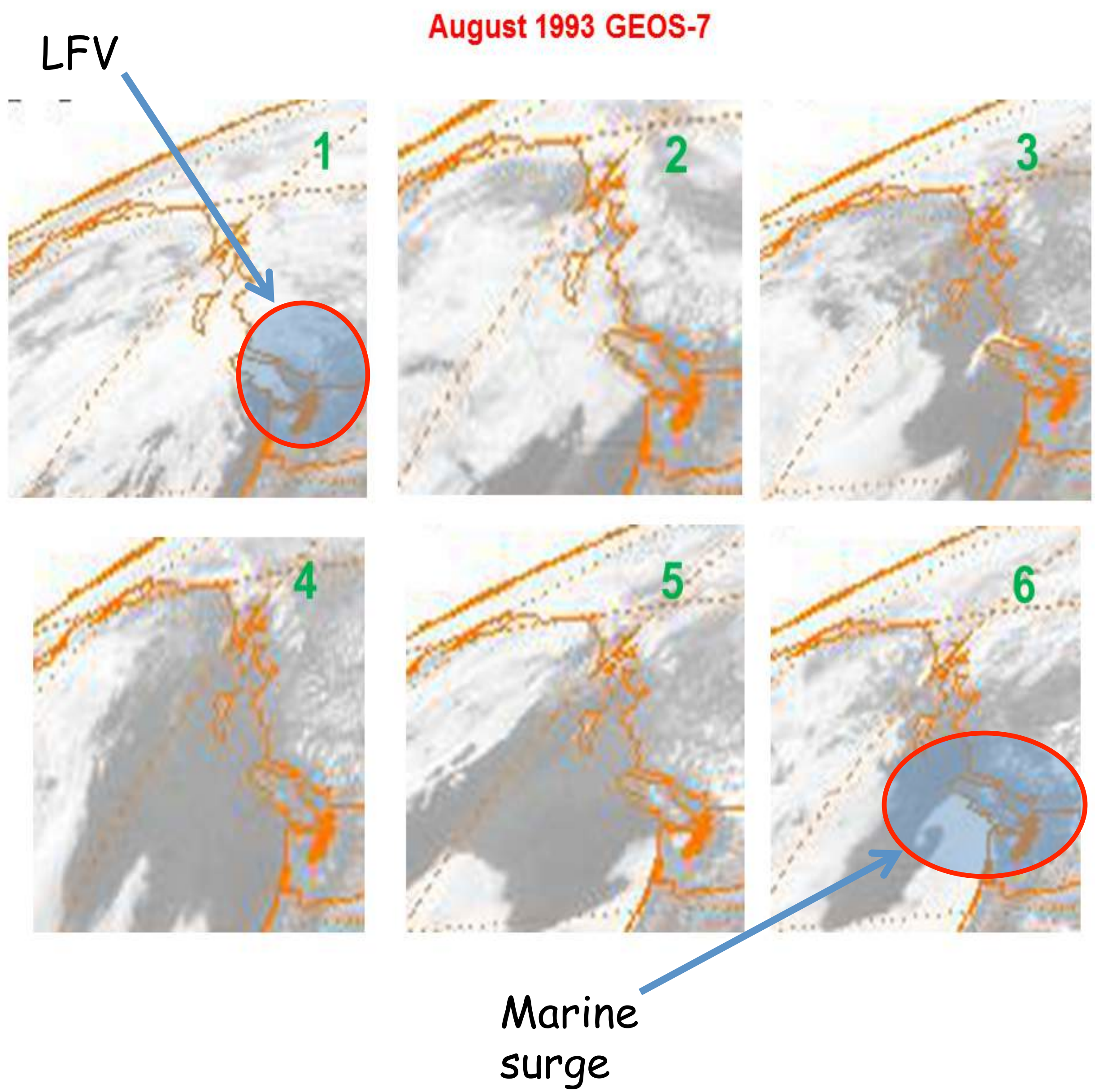
$$bag = 0.33\times[NO_2(ppb)]$$

AURAMS Aerosol → IMPROVE Reconstruction

Improve Category	AURAMS species											
Small sulphate	SU1	SU2	SU3	SU4								
Large sulphate	SU5	SU6	SU7	0.5*SU8								
Small nitrate	NO31	NO32	NO33	NO34								
Large nitrate	NO35	NO36	NO37	0.5*NO38								
Small Organic Mass	OC1	OC2	OC3	OC4	PC1	PC2	PC3	PC4				
Large Organic Mass	OC5	OC6	OC7	0.5*OC8	PC5	PC6	PC7	0.5*PC8				
Elemental Carbon	EC1	EC2	EC3	EC4	EC5	EC6	EC7	0.5*EC8				
Sea salt	SEA1	SEA2	SEA3	SEA4	SEA5	SEA6	SEA7	SEA8	SEA9	SEAA	SEAB	SEAC
Coarse Mass	SU5	SU6	SU7	0.5*SU8	NO35	NO36	NO37	0.5*NO38				
	OC5	OC6	OC7	0.5*OC8	PC5	PC6	PC7	0.5*PC8				
	EC5	EC6	EC7	0.5*EC8	SEA5	SEA6	SEA7	SEA8				
Fine Soil	CM1	CM2	CM3	CM4	CM5	CM6	CM7	0.5*CM8				

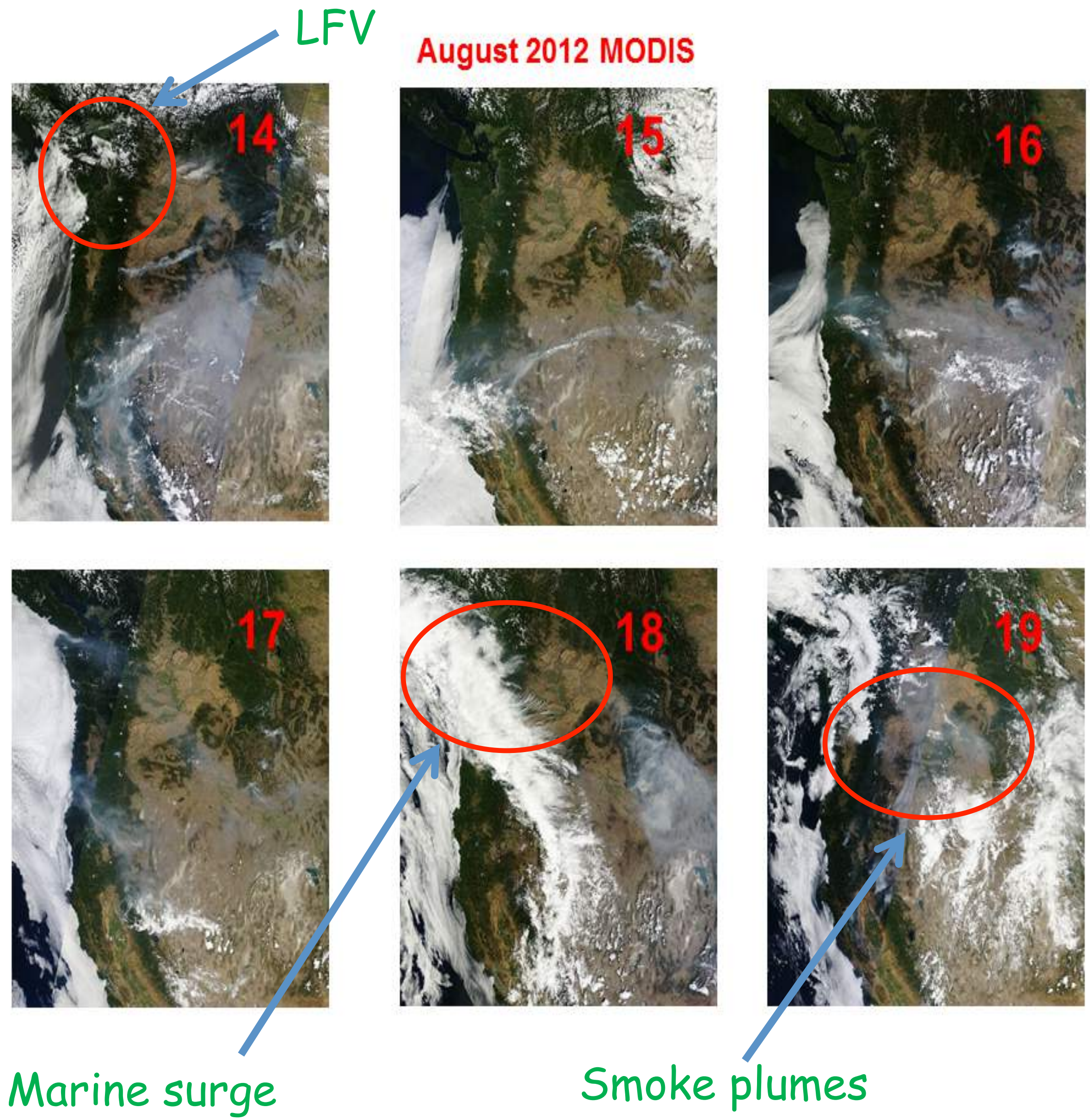
Modeled Episode Aug 1-5 1993

- Minor ozone episode characterized by modest 500 hPa ridging, clear skies and surface thermal trough (Aug 1-4)
- Breakdown of the ridge on Aug 5th led to advection of cool marine air (marine surge) and episode end on Aug 6th

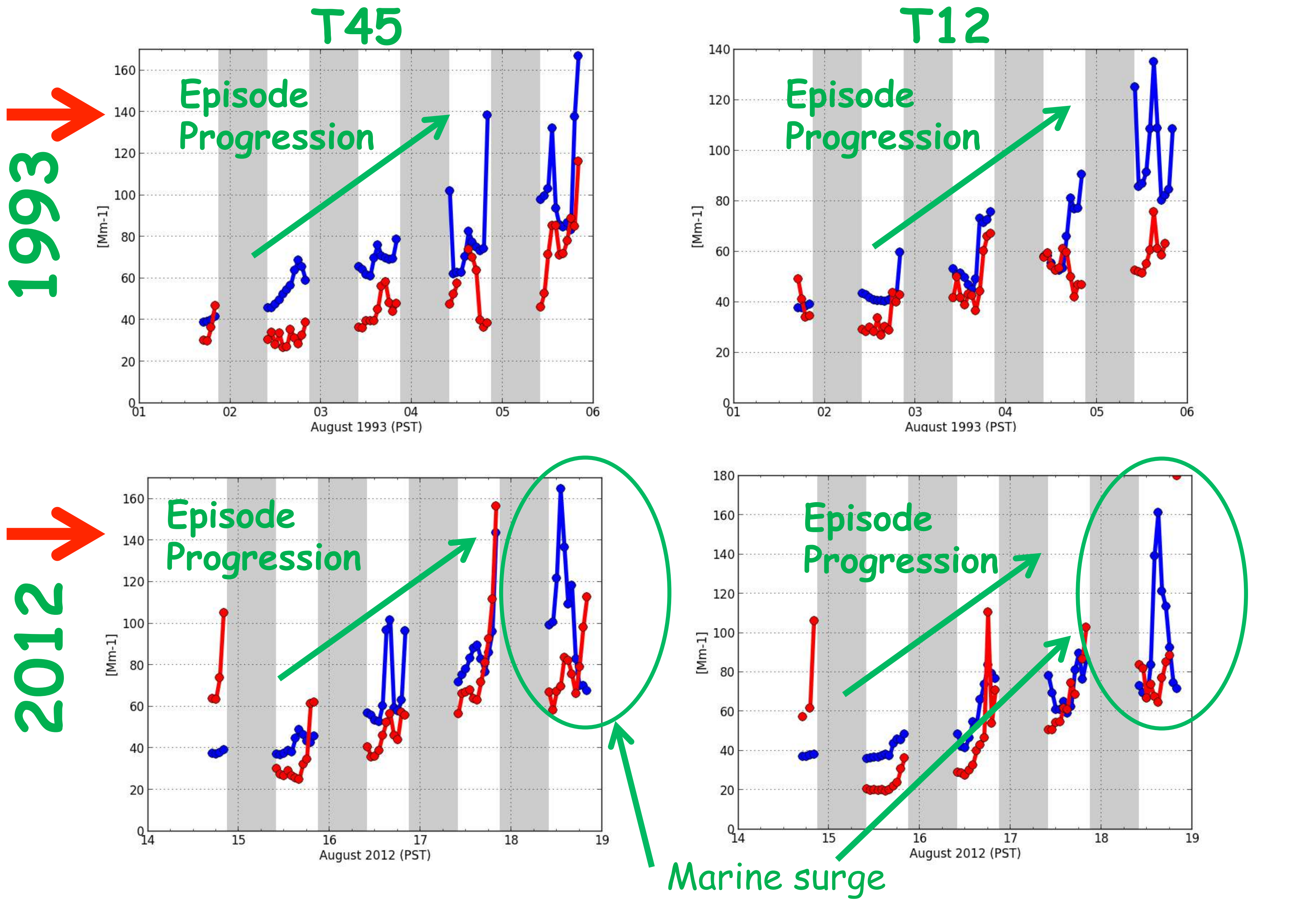


Modeled Episode Aug 15-19 2012

- Similar to 1993 event with upper-level ridging and surface thermal trough (Aug 14-17)
- Marine on Aug 18th ends episode
- Possible influence of wildfire smoke from U.S.



Modeled Bscat (bsg + bsp) in Mm^{-1}
blue-AURAMS red-Observations



Both Model and Observation show same level of extinction

Possible Reasons:

1. Visibility in airshed not responsive to emissions reductions (little policy possible)
2. Airshed is responsive but model is not (arghh!)
3. Chosen episodes are not analogues of one another with the 2012 being a more severe episode

Let's explore the 3rd option

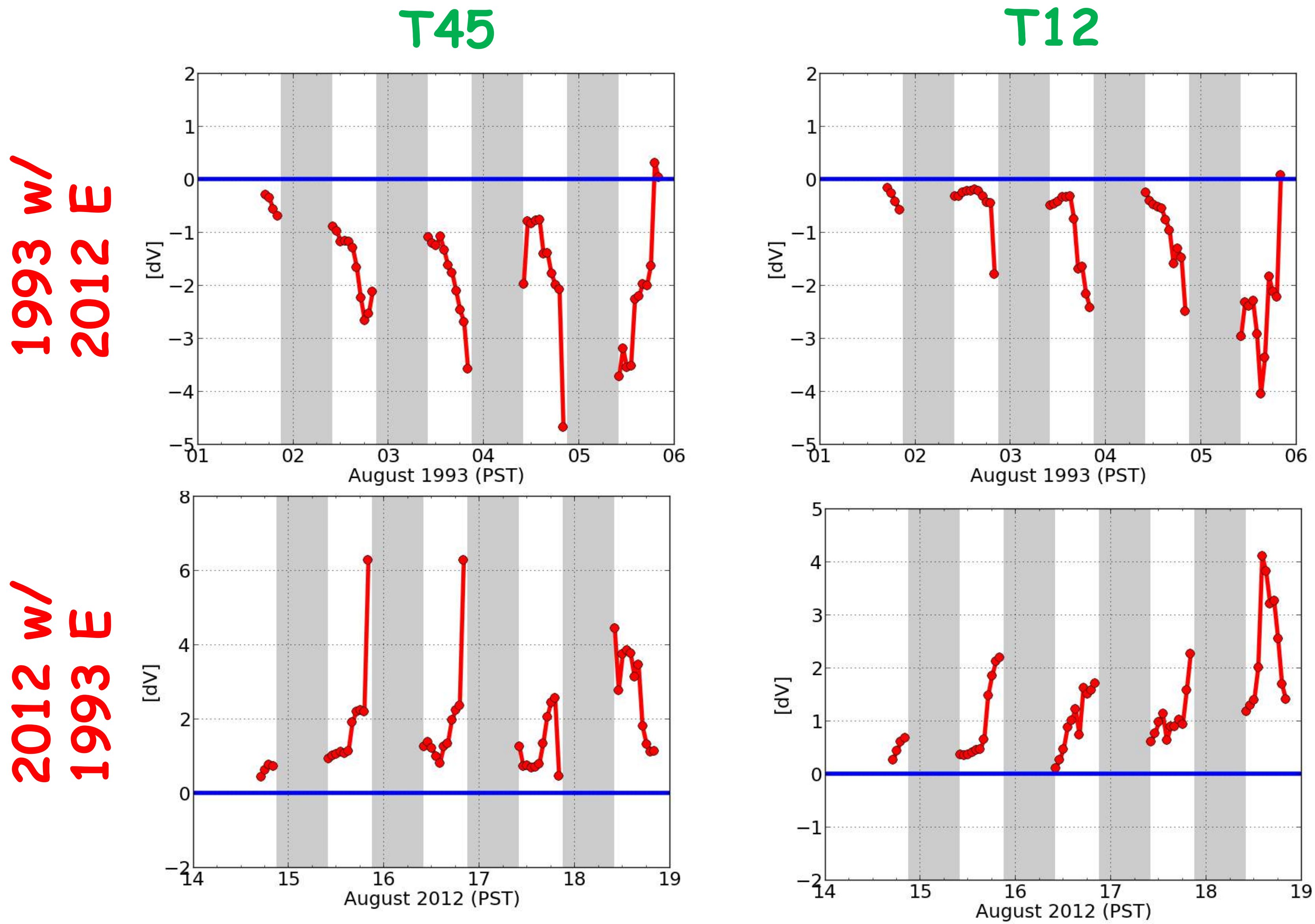
Re-run the model w/:

- **2012** episode with **1993** emissions and;
- **1993** episode with **2012** emissions
- Look at change in visibility in terms of changing deciview:

  dv = 10 ln (bext/10)

- Change of 1 dv equivalent to about 10% change in bext and relates to a small but perceptible change in visibility.

Modeled change in deciview (dV)



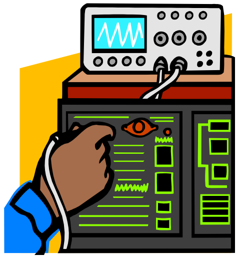
Interpreting the change in modeled visibility

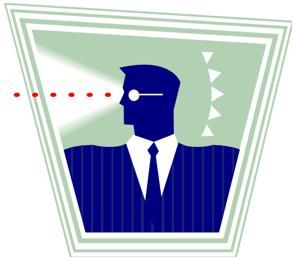
- Model shows change between 0 and 6 dV
- Is this significant?
- Local public perception study used to correlated Visual Range to perception of visibility impairment
- Visual Air Quality Rating (VAQR) developed
- Rating to has 5 categories:

  Excellent / Good / Fair / Poor / Very Poor

Public Perception Study (UBC 2011)

26 images looking SE from Chilliwack under wide range of visibility conditions shown to 301 participants





Visibility …

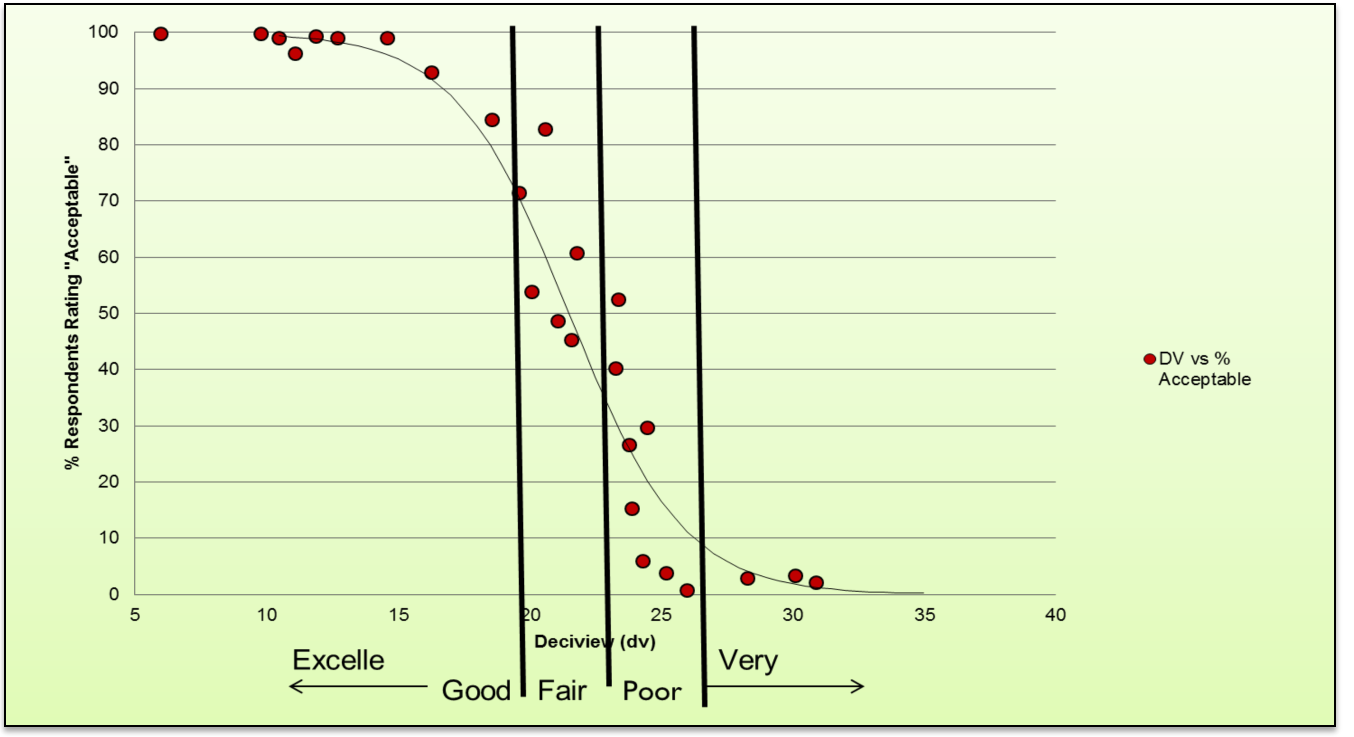
… measured:

bext (i.e.dv) using nephelometer, aethalometer, NO2

… scored:

As: acceptable / unacceptable

Visual Air Quality Rating: Based on % Scene Acceptability



VAQI Category	Dv	% Rating Acceptable
Excellent	<16	>95
Good	16-20	70 -95
Fair	20-23	40 – 70
Poor	23-26	10 – 40
Very Poor	>26	<10

Aug 4th 1993 T45 dV goes from 27 (very poor) to 23 (fair) using 2012 emissions

Very Poor (using 1993 emissions)

Fair (using 2012 emissions)

Aug 16th 2012 T45 dV goes from 17 (good) to 24 (poor) using 1993 emissions

Excellent (using 2012 emissions)

Fair (using 1993 emissions)

Ongoing Work

- Extend 1993 and 2012 simulations to include variety of meteorological conditions
- Perform categorical model evaluation using VAQI and model output
- Include update Ammonia and VOC inventories
- Include soon to be released 2010 emissions inventory

Future Work -- Policy Modeling Scenarios

Use meteorology from 2012 to simulate visiblity under range of emissions scenarios:

1. Those <u>currently</u> part of local airshed plans, incl. approved fed actions
2. Those considered for <u>future</u> airshed plans
3. Hypothetical scenarios tailored to address the pollutants most responsible for visibility loss

Scenarios can target visibility improvements for:

- The entire year
- A particular season
- Specific visibility conditions (eg. very poor visibility days)

Questions?

AURAMS 1.4.0/PMSizeFraction

< AURAMS 1.4.0

PM Size bin representation

Size cut off by aerosol aerodynamic radius / diameter:

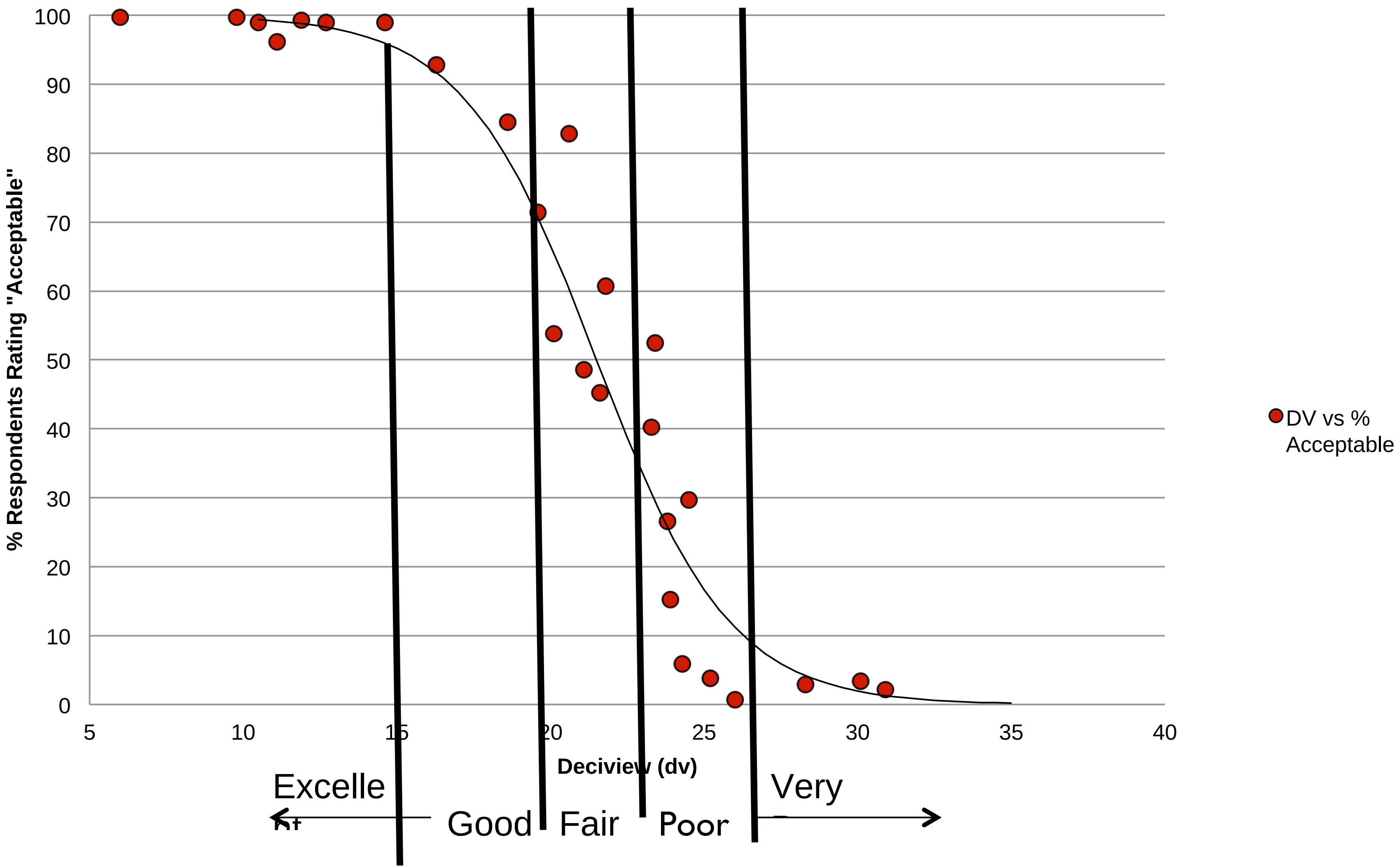
PM Size Bin

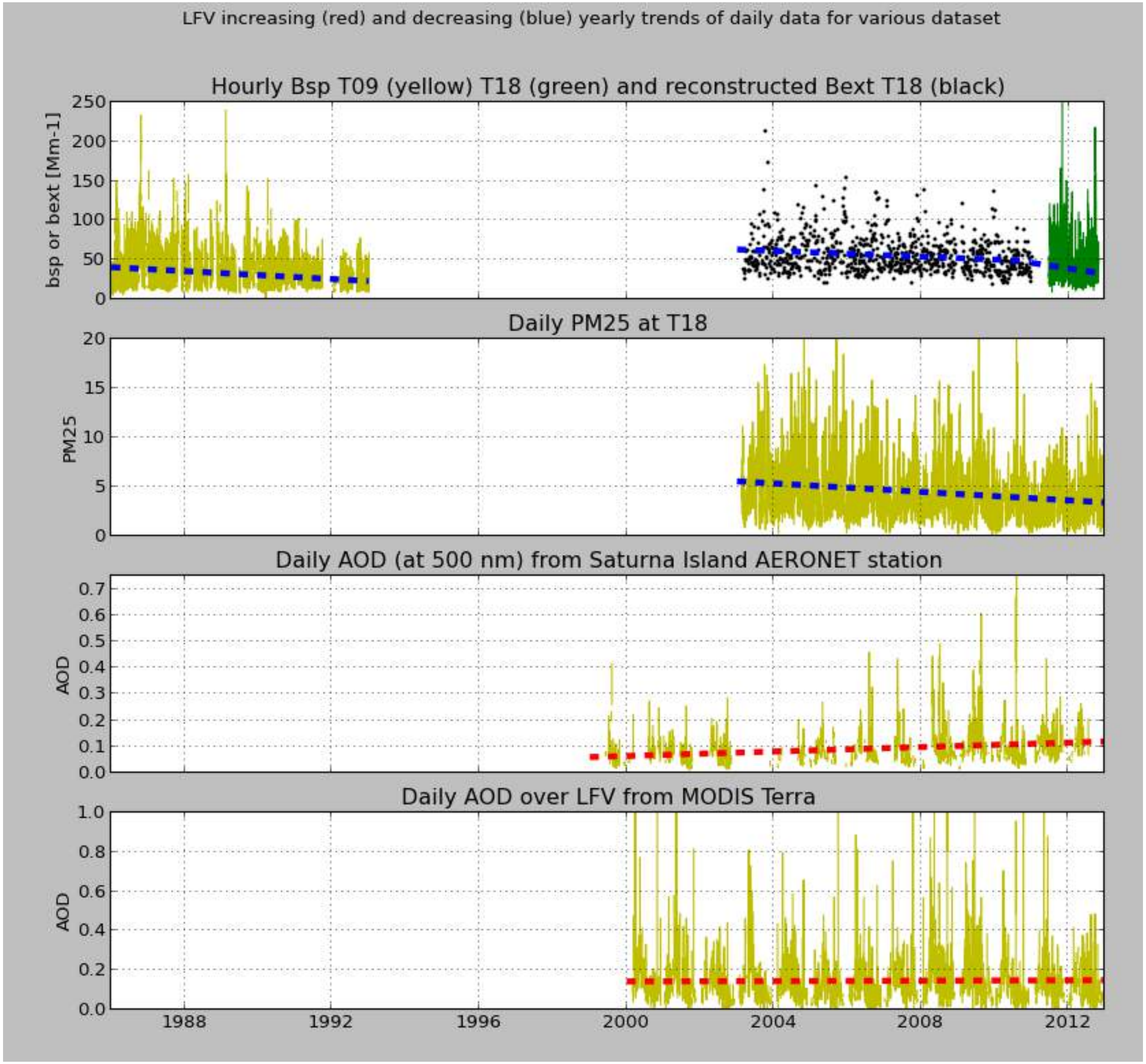
Bin#	Upper Bound Radius (um)	Lower Bound Radius (um)	Upper Bound Diameter (um)	Lower Bound Diameter (um)
Bin 1	0.005	0.01	0.01	0.02
Bin 2	0.01	0.02	0.02	0.04
Bin 3	0.02	0.04	0.04	0.08
Bin 4	0.04	0.08	0.08	0.16
Bin 5	0.08	0.16	0.16	0.32
Bin 6	0.16	0.32	0.32	0.64
Bin 7	0.32	0.64	0.64	1.28
Bin 8	0.64	1.28	1.28	2.56
Bin 9	1.28	2.56	2.56	5.12
Bin 10	2.56	5.12	5.12	10.24
Bin 11	5.12	10.24	10.24	20.48
Bin 12	10.24	20.48	20.48	40.96

The PM size cut-off are listed/configured in the AURAMS's namelist input file (masterlist_soa_rm.txt) as follows (the size definition is handled in `<rebin.ftn90> as: "radius(n) = 0.5 * 100.0 * (aerosize(1,n) + aerosize(2,n))"`

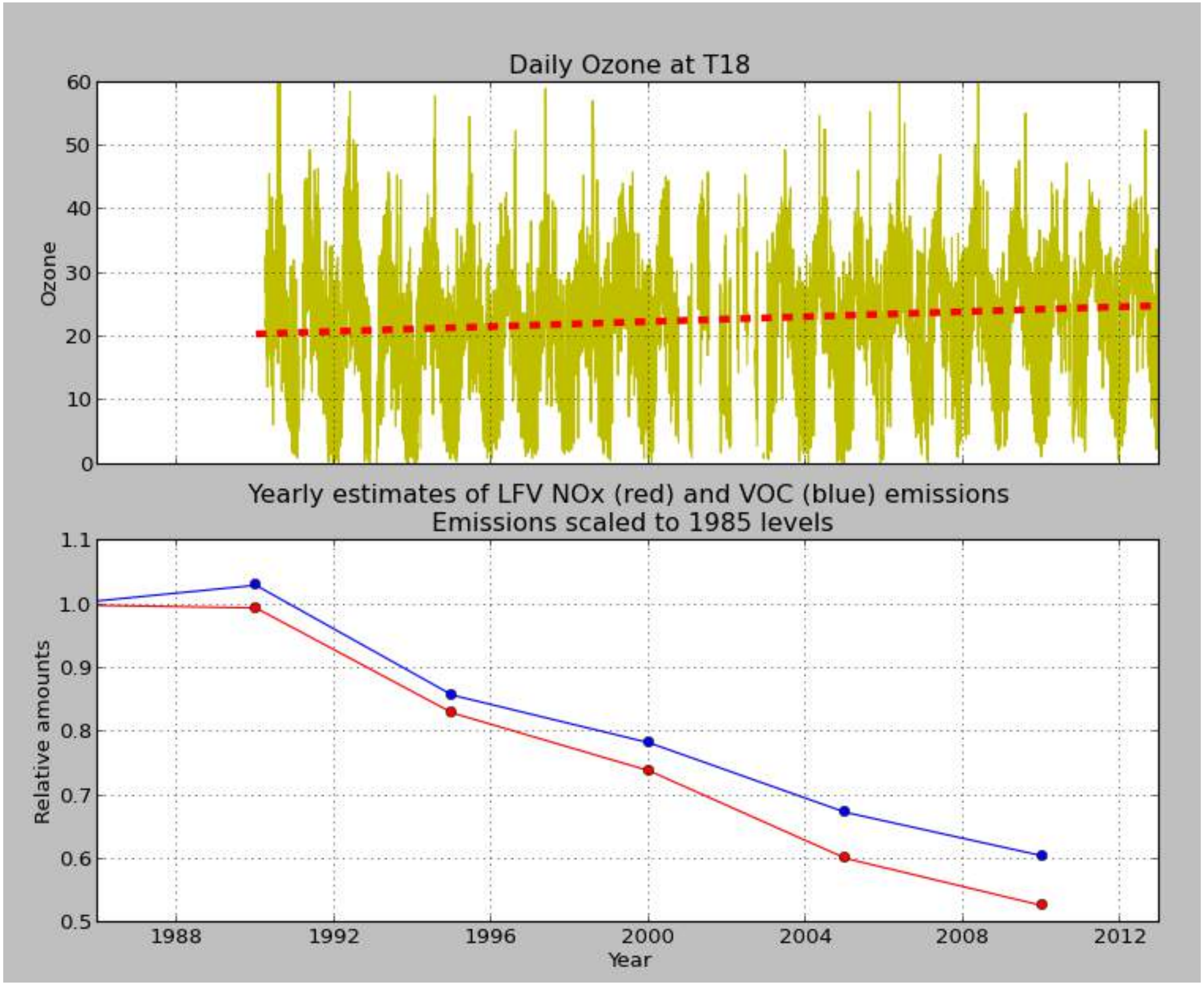
```
#        . . . . . . . . . . . . . . Size Spectrum  (PM radius) . . . . . . . . . . . . . . . .
b01="   0.005"; b02="    0.01"; b03="    0.02"; b04="    0.04"; b05="    0.08";
b06="    0.16"; b07="    0.32"; b08="    0.64"; b09="    1.28"; b10="    2.56";
b11="    5.12"; b12="   10.24"; b13="   20.48"; b14="        "; b15="        ";
b16="        "; b17="        "; b18="        "; b19="        "; b20="        ";
b21="        "; b22="        "; b23="        "; b24="        "; b25="        ";
b26="        "; b27="        "; b28="        "; b29="        "; b30="        ";
b31="        "; b32="        "; b33="        "; b34="        "; b35="        ";
b36="        "; b37="        "; b38="        "; b39="        "; b40="        ";
```

Scene Acceptability versus Visual Range



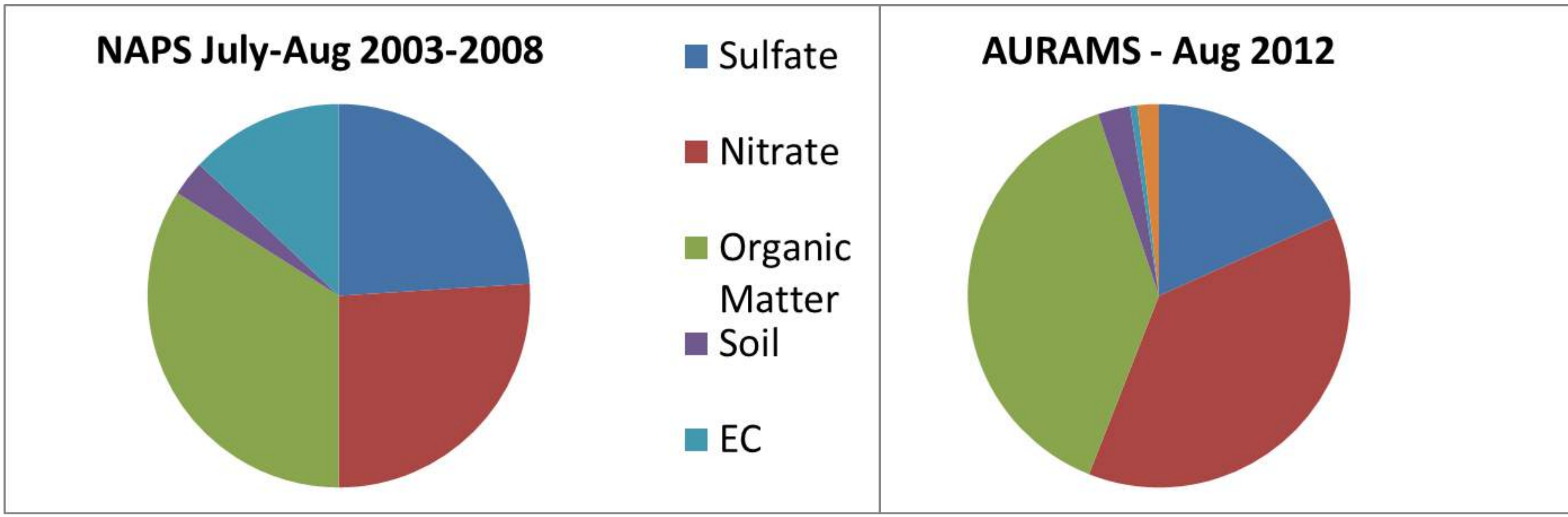


LFV increasing (red) and decreasing (blue) yearly trends of daily data for various dataset
Hourly Bsp T09 (yellow) T18 (green) and reconstructed Bext T18 (black)
bsp or bext [Mm-1]
250
200
150
100
50
0
Daily PM25 at T18
PM25
20
15
10
5
0
Daily AOD (at 500 nm) from Saturna Island AERONET station
AOD
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Daily AOD over LFV from MODIS Terra
AOD
1.0
0.8
0.6
0.4
0.2
0.0
1988
1992
1996
2000
2004
2008
2012

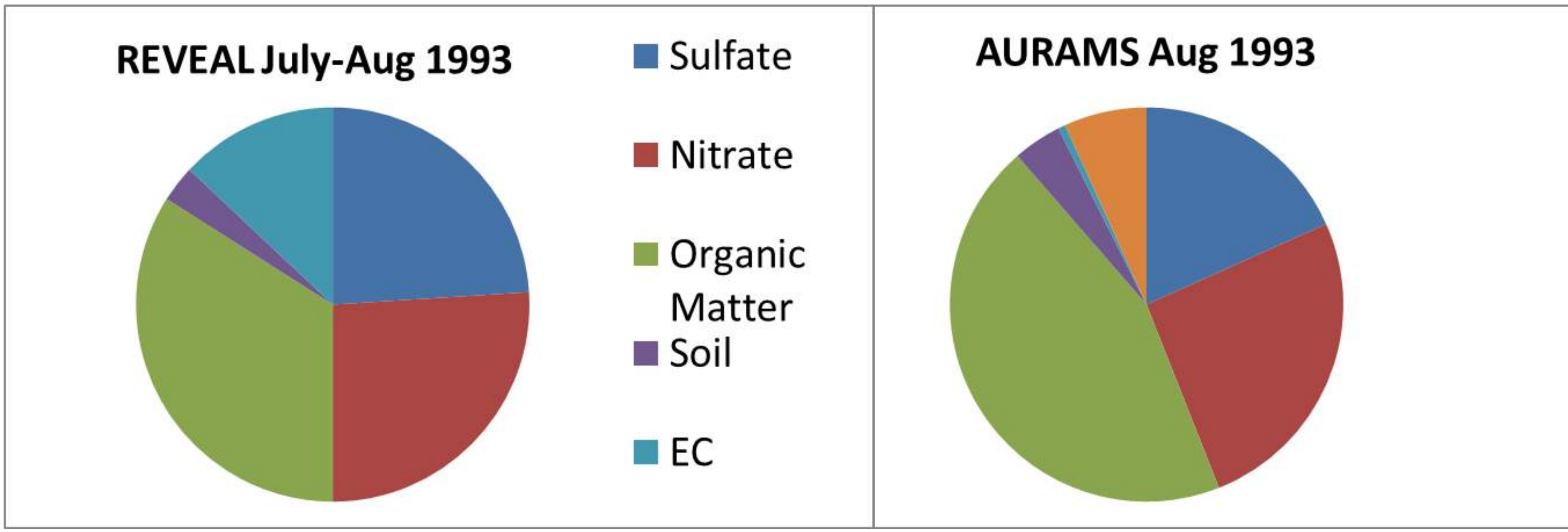


Daily Ozone at T18
Ozone
60
50
40
30
20
10
0
Yearly estimates of LFV NOx (red) and VOC (blue) emissions
Emissions scaled to 1985 levels
Relative amounts
1.1
1.0
0.9
0.8
0.7
0.6
0.5
1988
1992
1996
2000
2004
2008
2012
Year

T34 PM2.5 Mass Reconstruction 2012



T18 PM2.5 Mass Reconstruction - 1993

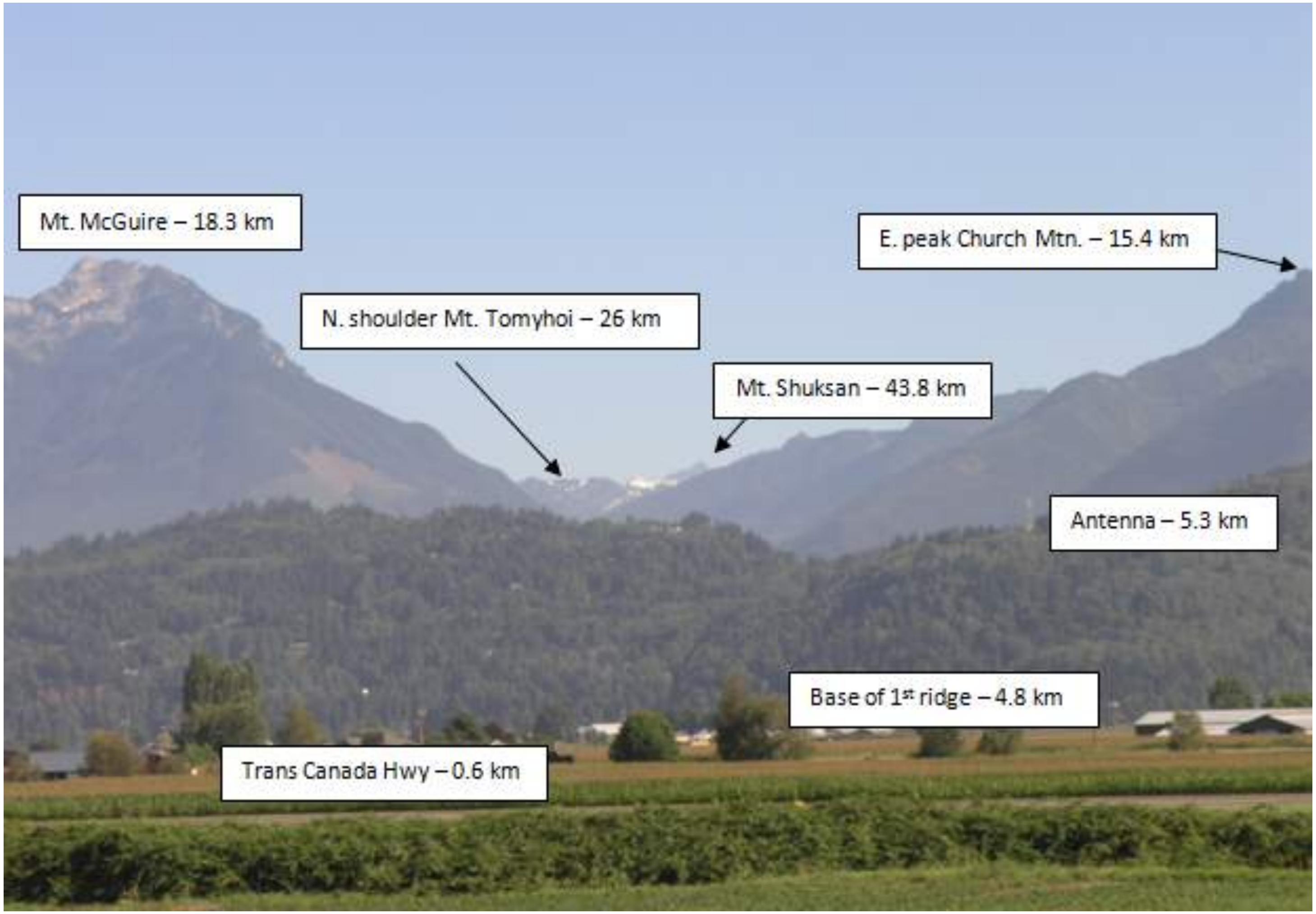


How do we assess visibility?

- Viewing distant landmarks most straight forward method used to assess visibility
- Visibility can thus be characterized by visual range
  - VR ~ 300 km pristine
  - ~ 100 km clean humid environment
  - ~ 10 km very hazy

"Visibility was less than 100 metres in some areas of eastern China"
CBC News, Jan 28, 2012

Archived images from T12 under variety of measured conditions used to display change in visibility



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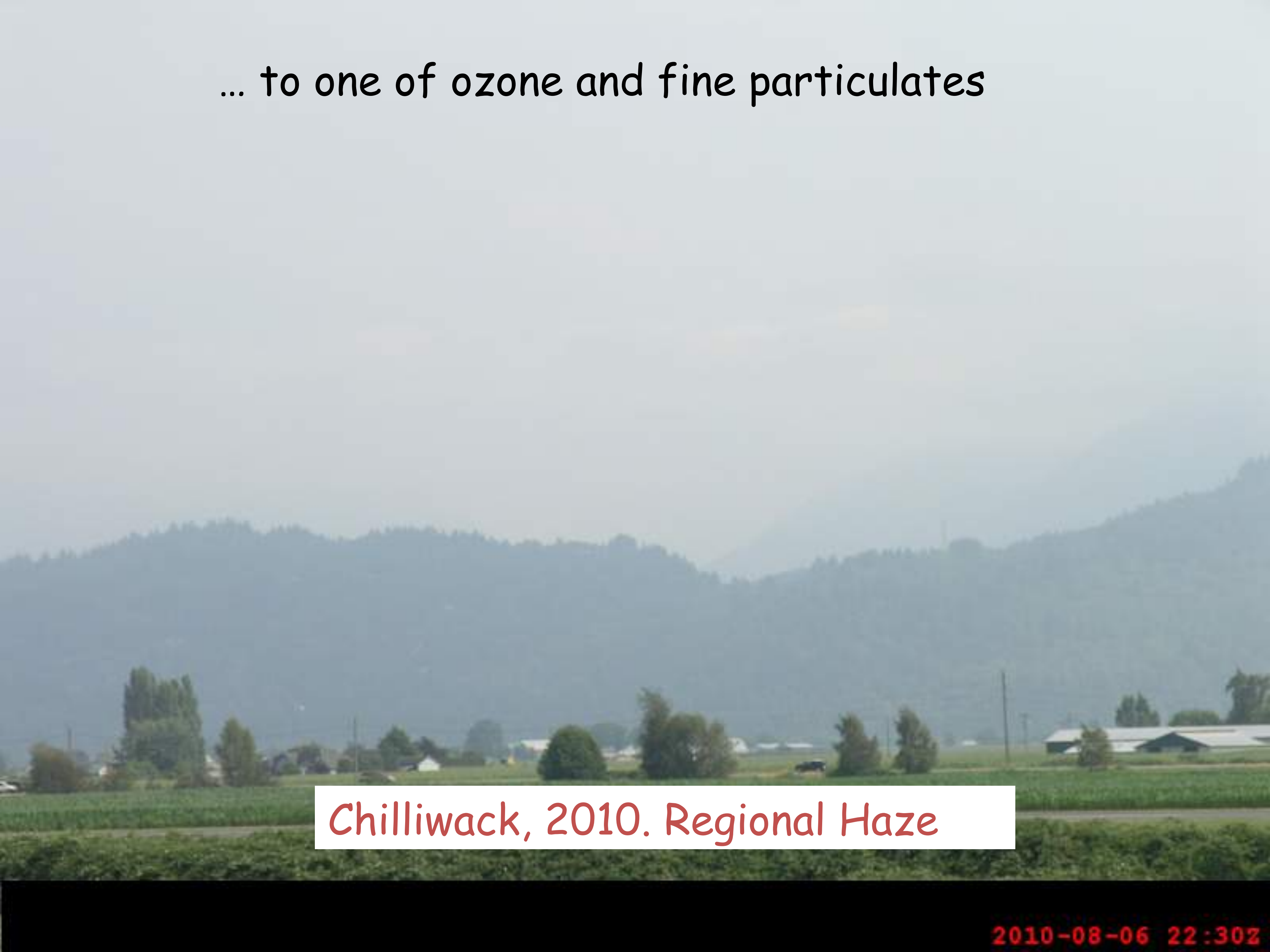
… to one of ozone and fine particulates
Chilliwack, 2010. Regional Haze
2010-08-06 22:30Z

Emission Scenarios

Emissions Reductions	Emission Sources
10 % 25 % 50 % 75 %	VOC/NOx/NH3/SO2/PM25
	VOC+NOx+NH3+SO2+PM25
	Marine only LDV only HDV only Burning only etc...

Future Work -- Source Apportionment

- Which emissions sources/sectors contribute the most to visual degradation?
- Analyze PM25 filters for different species (e.g. elemental carbon, organic matter …)
- Associate relative abundance of these species with emission source signatures (PMF)

Apportioned $PM_{2.5}$ (PMF)