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A Dynamic Model Evaluation of AURAMS for Visual Air Quality Policy Work in the Lower Fraser Valley, B.C.

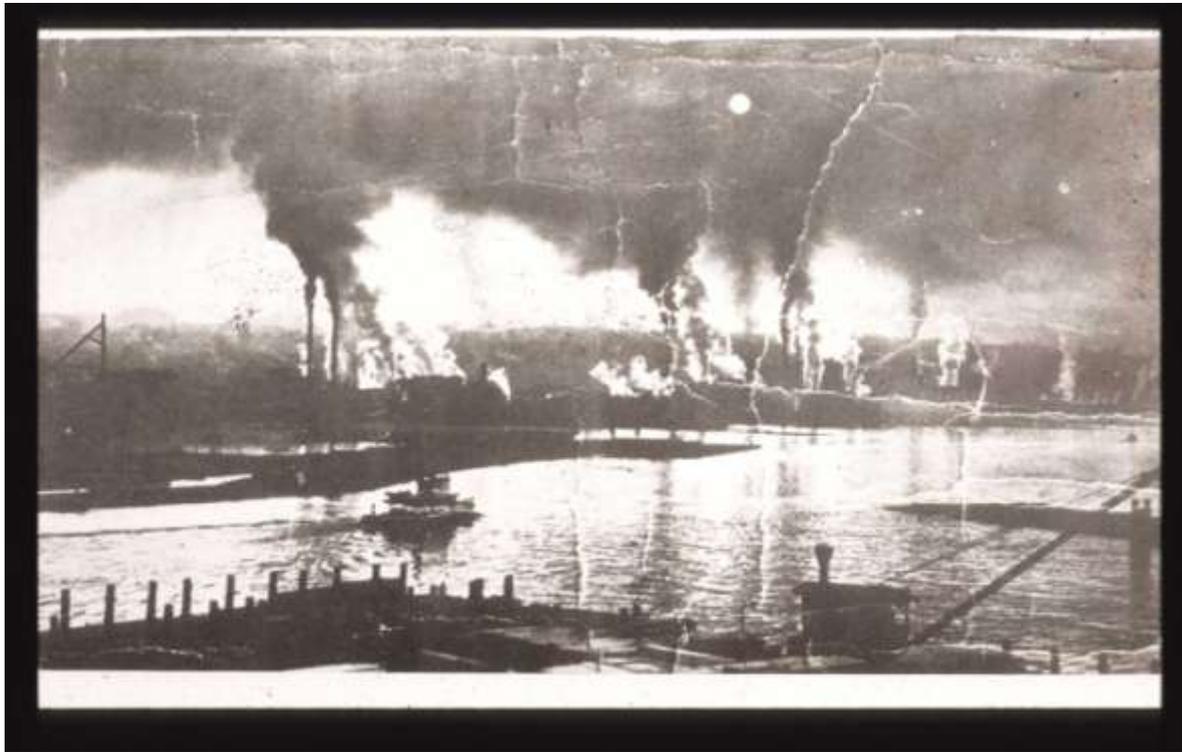
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Background

- 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



British Columbia Visibility Coordinating Committee (BCVCC)

A committee of Regional, Provincial and Federal agencies:



Ministry of
Environment



Environment
Canada

Environnement
Canada



Health
Canada

Santé
Canada



Metro Vancouver



Fraser Valley
Regional District



BCVCC has adopted 4-pronged approach to managing visibility:

- Science: monitoring, **modelling** and data analysis
- Visibility Index and Public perception
- Economic analysis
- Strategic Outreach - communications, website

Visibility Modeling Strategy

Objective

- Explore impacts of potential future emission changes on local visibility via numerical modeling

Concern

- How do we test the reliability of the model to answer such questions? ~~GIGO~~

Requirements

- Need to show model is both model **sensitive** to emissions changes and these sensitivities are **accurate**

Method

- Dynamically evaluate model using range of historical episodes

Dynamic Evaluation

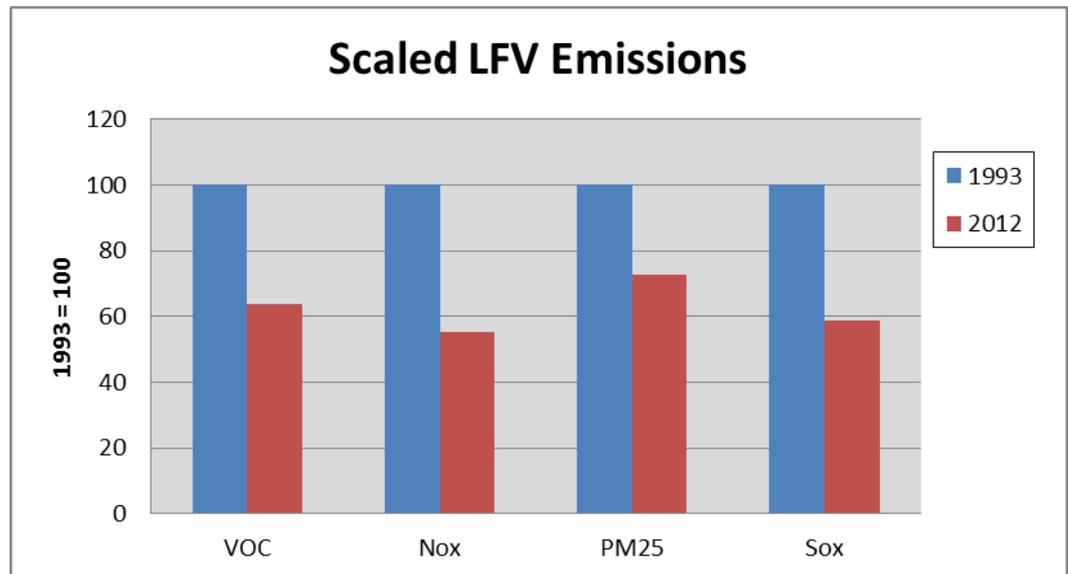
Explore model **fitness** by **exercising** it across range of historic episodes representing:

- I) **Different emission regimes** to test sensitivity to large scale emissions reductions
- II) **Different weather pattern** to test sensitivity to local variability

Exercising the Model I

- Model needs to faithfully represent response of airshed to potentially large (~50%) **future** emissions reductions
- Use 'natural experiment' undergone in LFV since the 1990s to test model's behaviour across the similar-sized **past** emission changes

Since early 1990's LFV undergone sizeable emission reductions



Use history to **REVEAL** model behavior

Past (1993)

- During July-August 1993 extensive field campaign to measure visibility in the LFV
- **REVEAL** (Regional Visibility Experimental Assessment in the LFV)
- Hourly measurements of extinction & speciated PM25 along with ozone and NOx
- Part of larger Pacific '93

Present(2012)

- EC's visibility monitoring network data
- MV hourly ozone, PM25, NOx
- NAPS speciated PM25

Model Framework

Run EC's AURAMS model for 2 short (4-day) ozone episodes:

- one during REVEAL campaign (1993)
- one during summer 2012

Nest domain down to 4km resolution

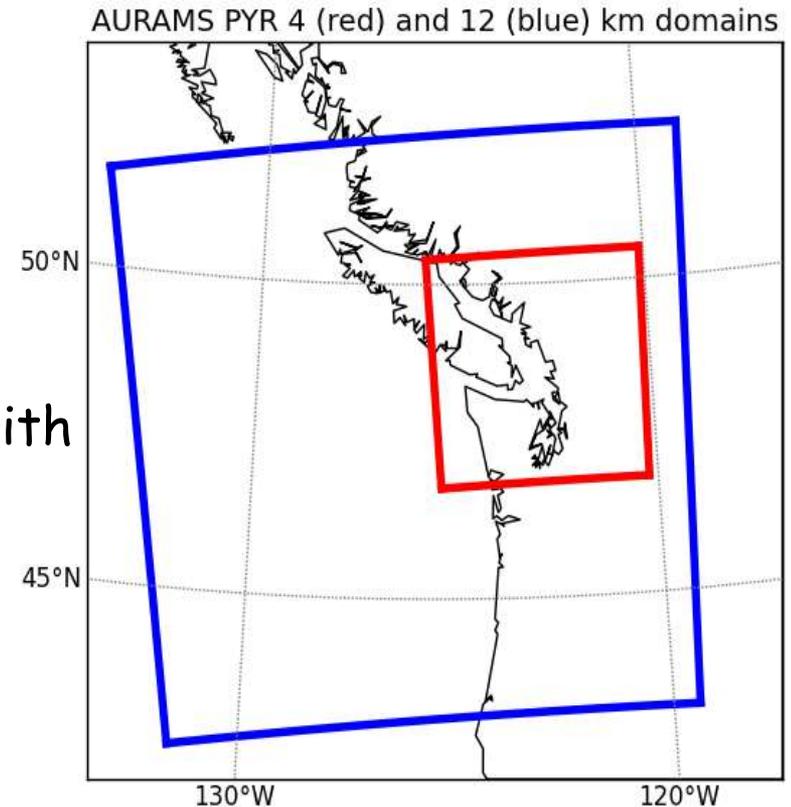
Particle physics and chemistry handled with 12 size bin particle speciation

Emissions from SMOKE using:

- EC 2010 Cdn and 2008 US emissions
- MV emission backcasts for scaling

Meteorology via GEM4.4

- West LAM domain: 180x166 @15km and 675x476 @2.5km
- For 1993 using Global Reanalysis (on Gaussian Grid) and Force Restore
- For 2012 using Regional Eta and ISBA

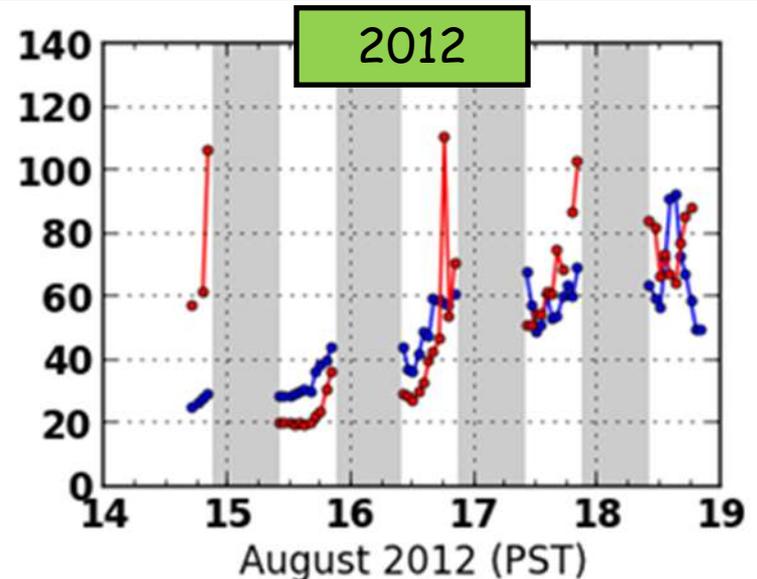
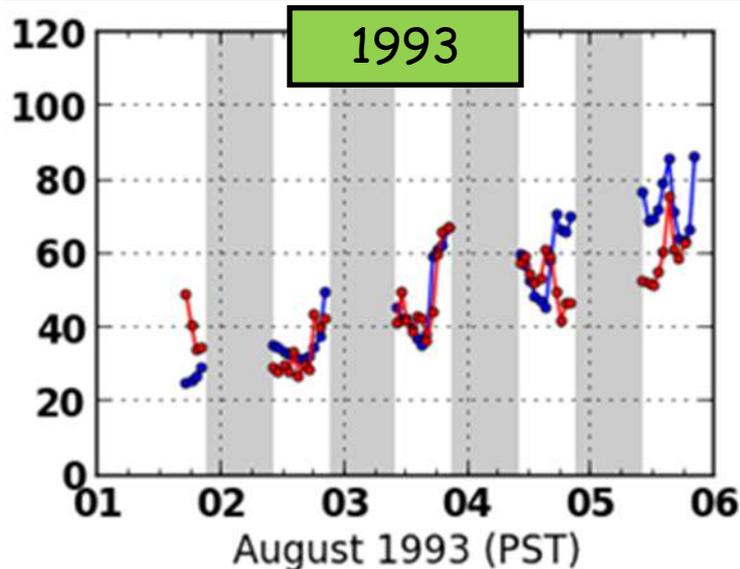


Summary - Exercising the Model I

- AURAMS modeling system was exercised over 2 episodes spanning 20-year interval
- During this time large (~40%) reduction in emissions
- Model reproduces ozone and extinction timeseries
→ Model sensitive to large scale emission changes

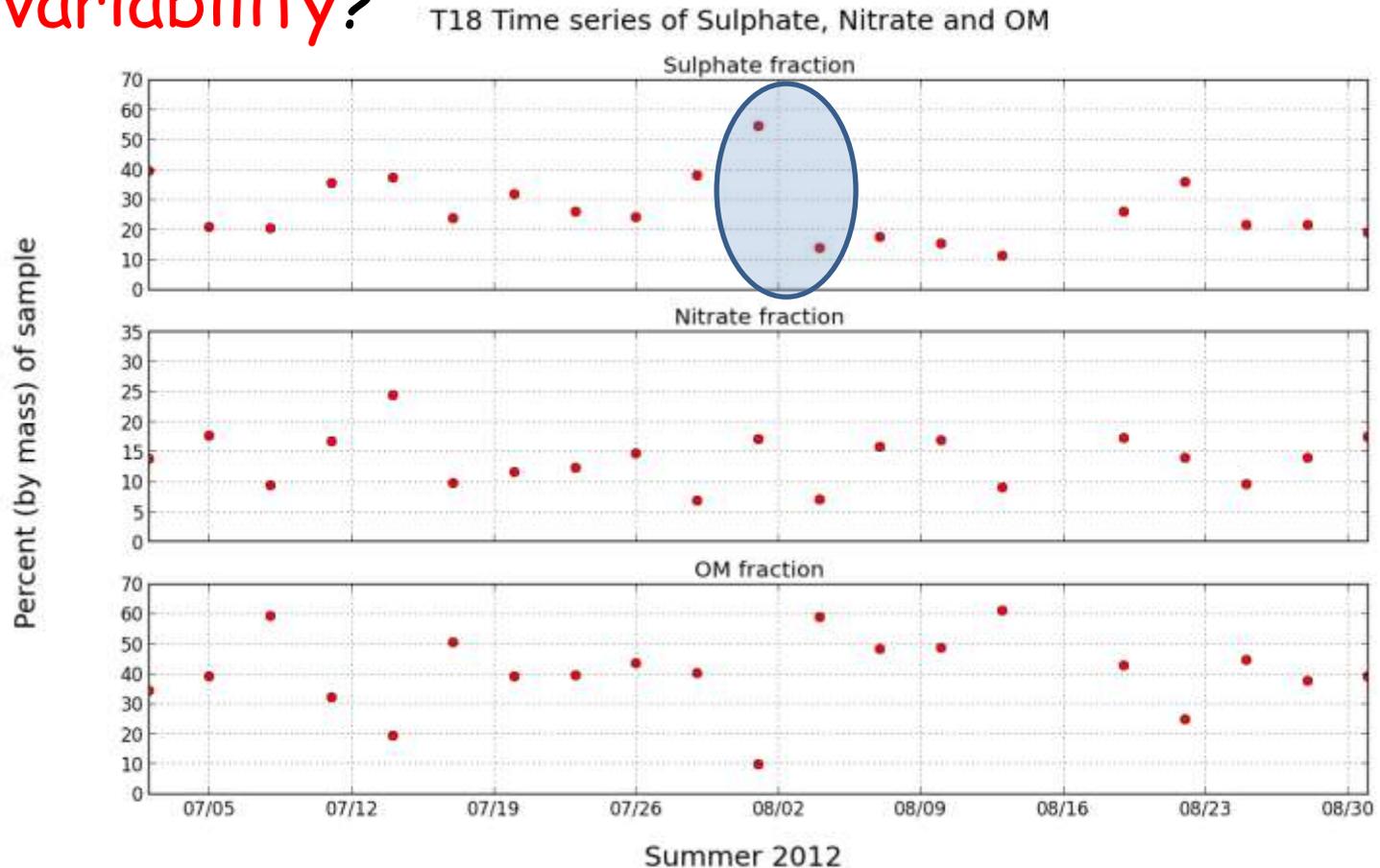
Bscat (bsg + bsp) in Mm^{-1}

Blue-AURAMS (via IMPROVE) Red-Observations (nephelometer)



Exercising the Model II

- Model sensitive to **large scale emissions changes** but does it capture **day-to-day variability**?



Why does the PM₂₅ speciation vary so much between days?

- Synoptic conditions during summer fairly constant and there is little long-range pollutant transport into LFV.
 - If its meteorology, caused by meso-scale variability.
- **QUESTION:** Do the mass fraction samples occur in a few distinct configurations ('fingerprints'), or can the mass fractions of each species occur in any proportion?
 - Perform a clustering analysis to see if distinct mass fraction regimes occur.
- Use this to investigate possible controls on the observed variability.
- **ASK:** *How well does AURAMS capture these meteorological controls?*

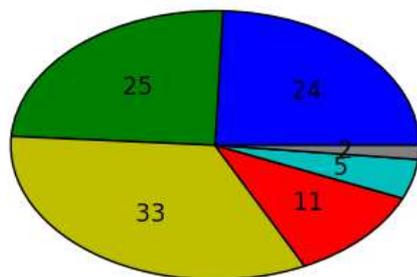
T18 and T34 NAPS FineMass Clustering

- Look at daily PM₂₅ speciation for summer (JJA) days between 2003-2012
- For each daily sample find % of PM₂₅ mass as a function of:
 - Sulphate, Nitrate, Organic Matter, Elemental Carbon, Soil and Sea Salt**
- Perform hierarchical then Kmeans clustering on each sample, sort samples with similar breakdowns into common groups
- Cluster each dataset independently
- Clustering finds 3 clusters at both locations

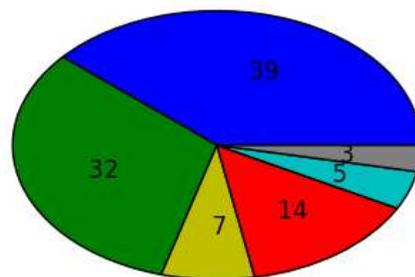
Typical Days (65 of 134 samples)

Sulphate Days (17 of 134 samples)

Typical

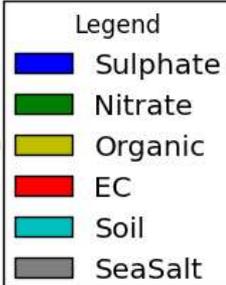
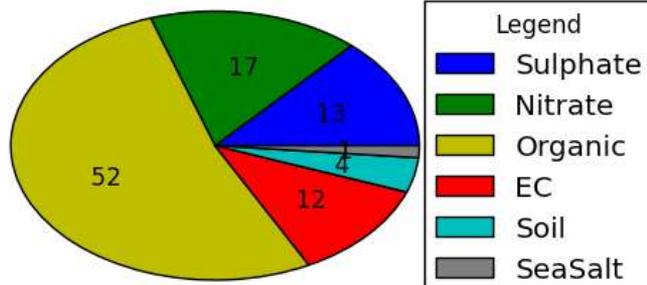


Sulphate



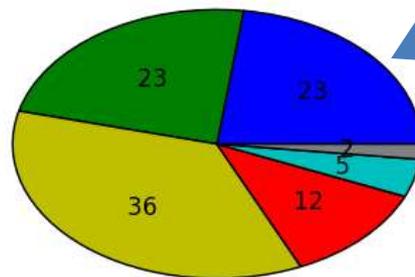
OM Days (38 of 134 samples)

OM



2003-2012
Average

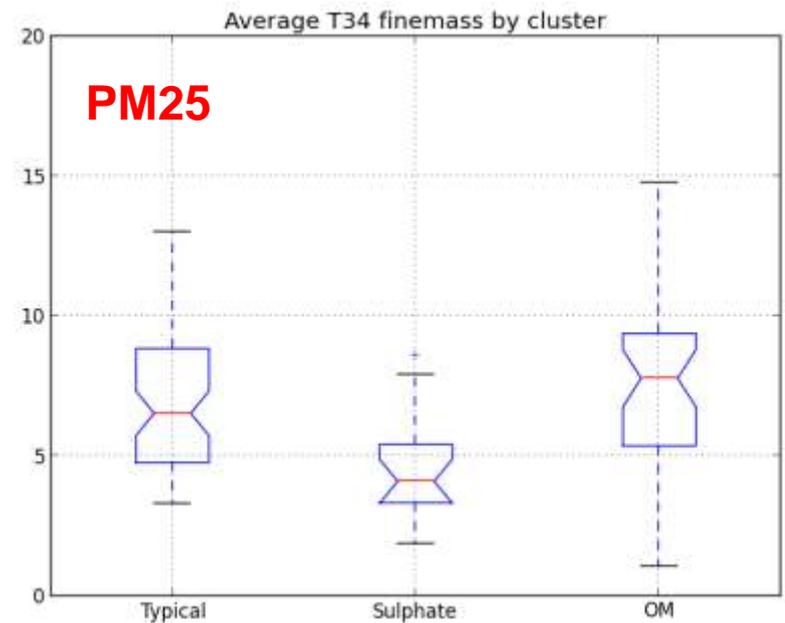
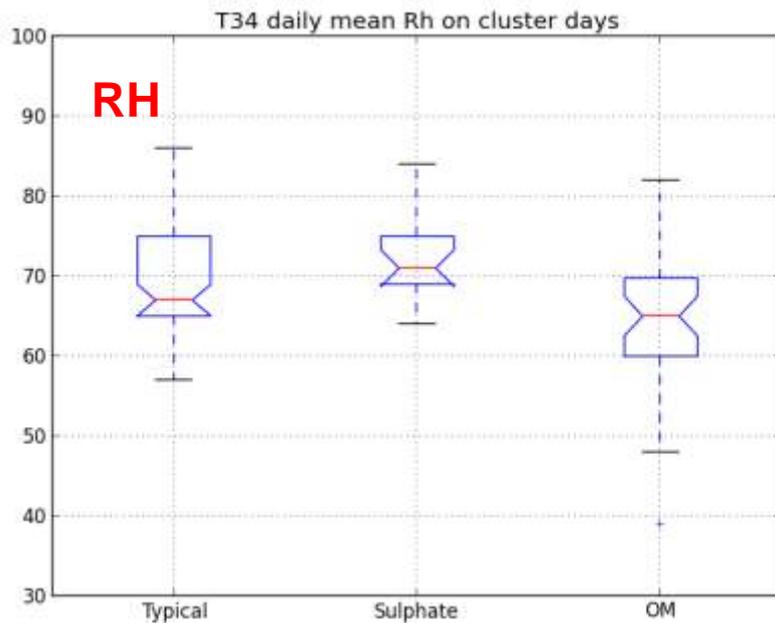
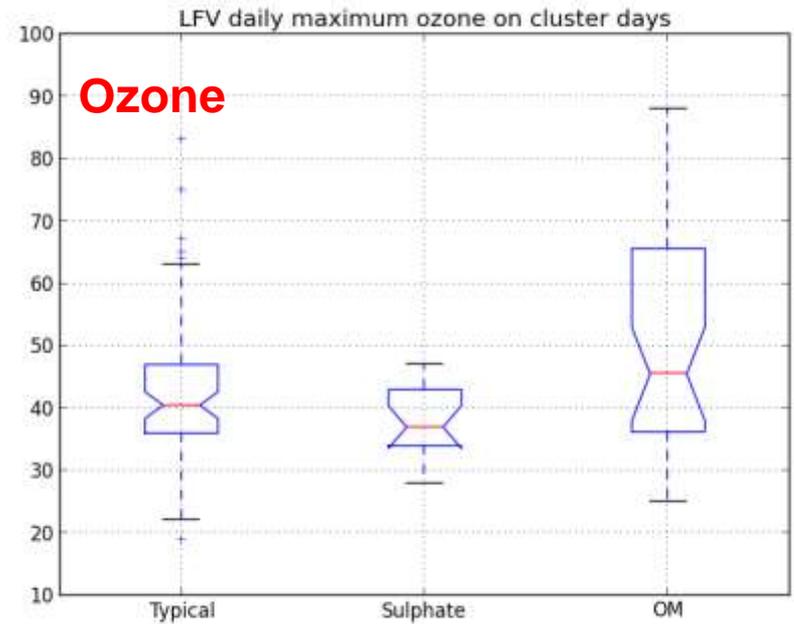
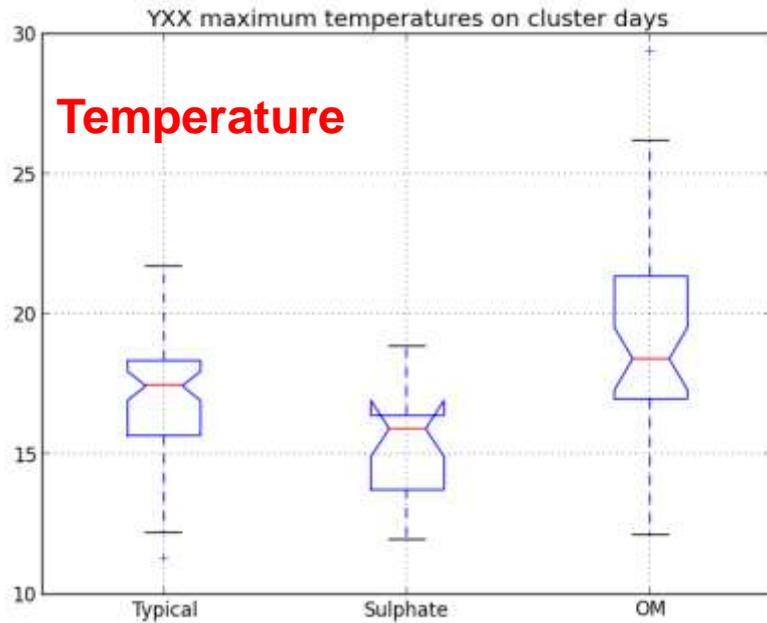
All Days (134 samples)



3 Clusters:

1. OM enriched
2. Sulphate enriched
3. OM-Nitrate-Sulphate balanced (typical)

Environmental conditions associated with each cluster



Key Day Analysis

- Identify a representative day from each cluster
- Note that on some days, there are NAPS samples at **BOTH T34** and **T18**
- Find a "**Sulphate**", "**OM**" and "**Typical**" day which has measurements at both **T18** and **T34 AND** is classified in the same way by both clusterings.

More Modeling

- Run AURAMS over 4-day episode in order to capture each of the key days

OM Episode:

- June 23-26, 2006 with key day on June 25th

Sulphate Episode:

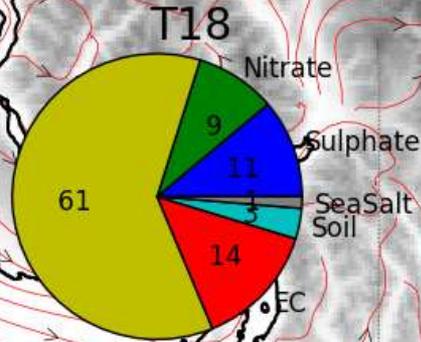
- August 8-11, 2007 w/ key day on August 10th

Typical Episode:

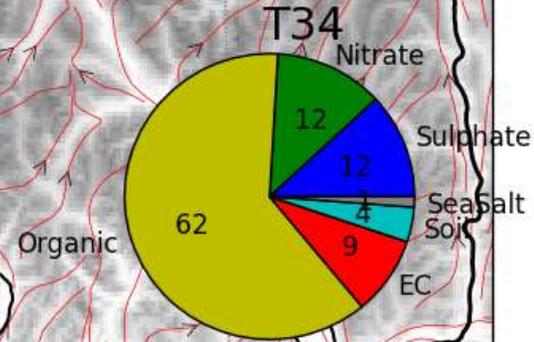
- Aug/Sep 28-1, 2012 w/ key day August 31st

OM Key Day

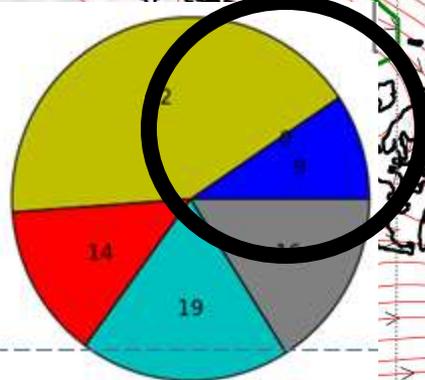
NAPS
T18



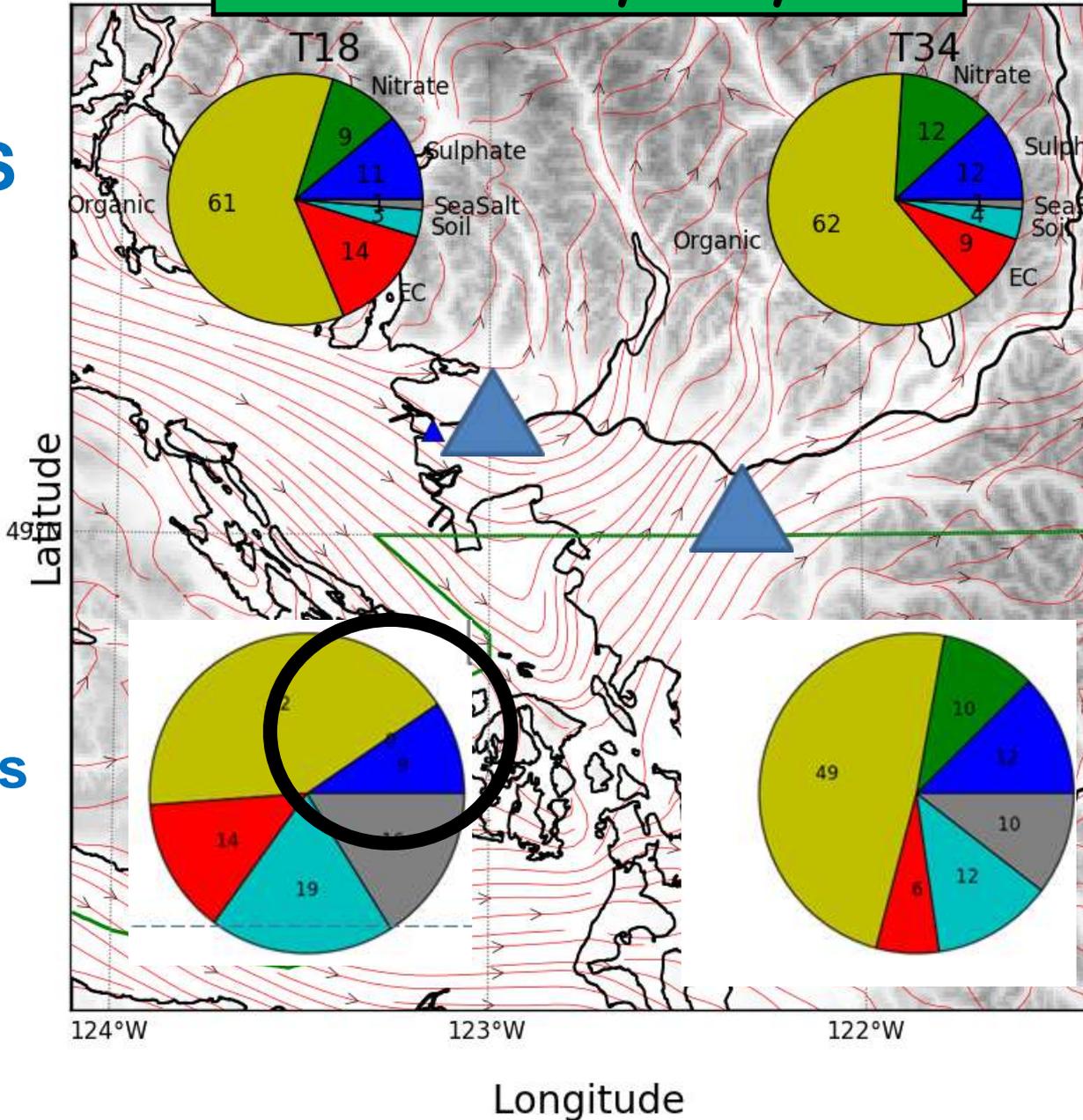
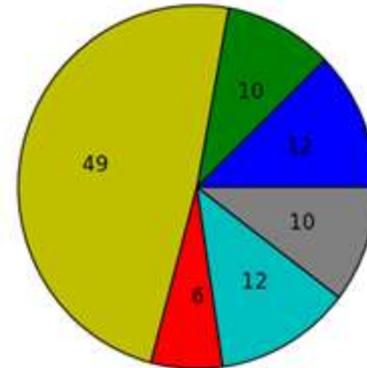
NAPS
T34



Aurams
T18



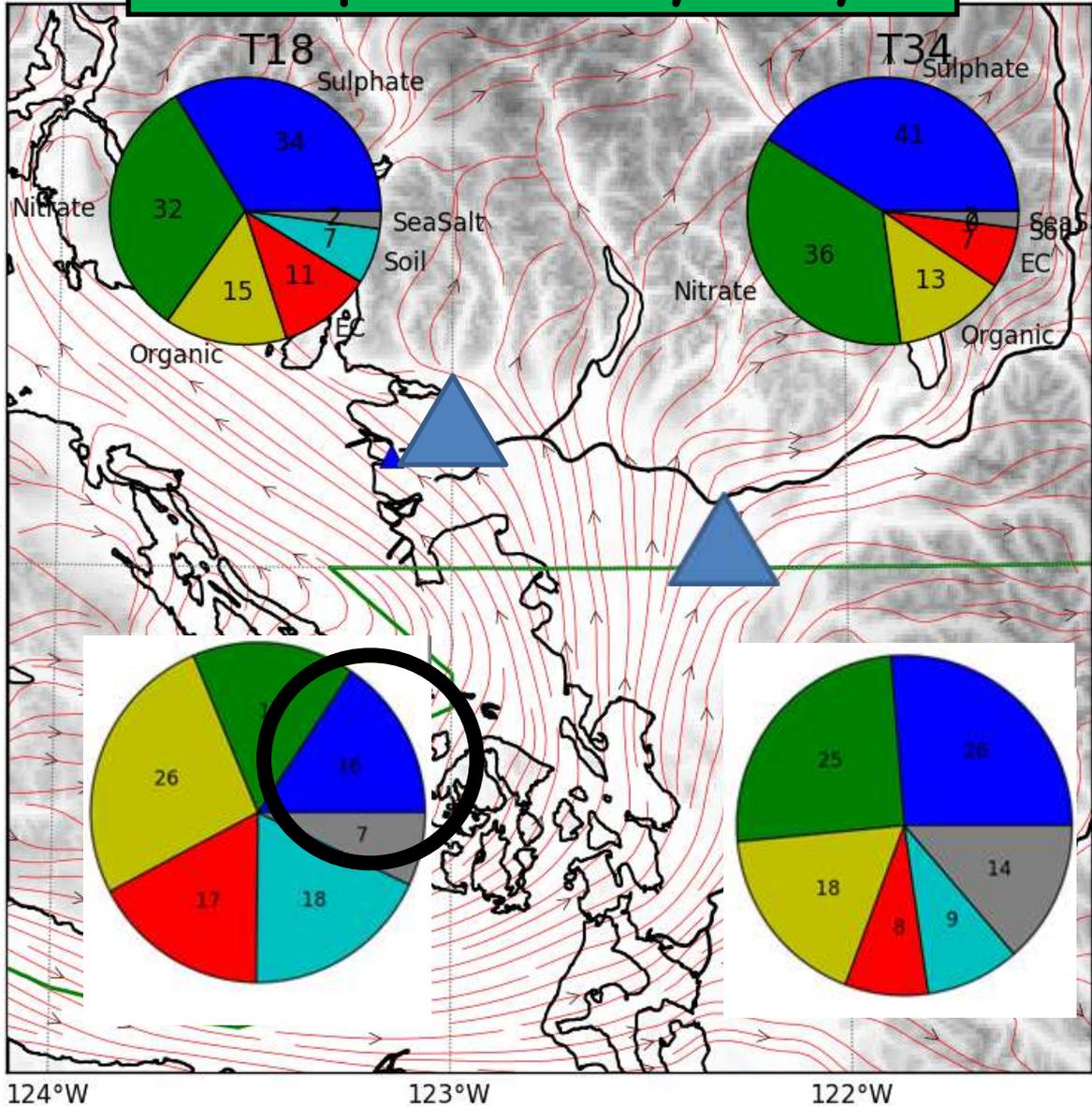
Aurams
T34



Longitude

Sulphate Key Day

NAPS
T18



NAPS
T34

Aurams
T18

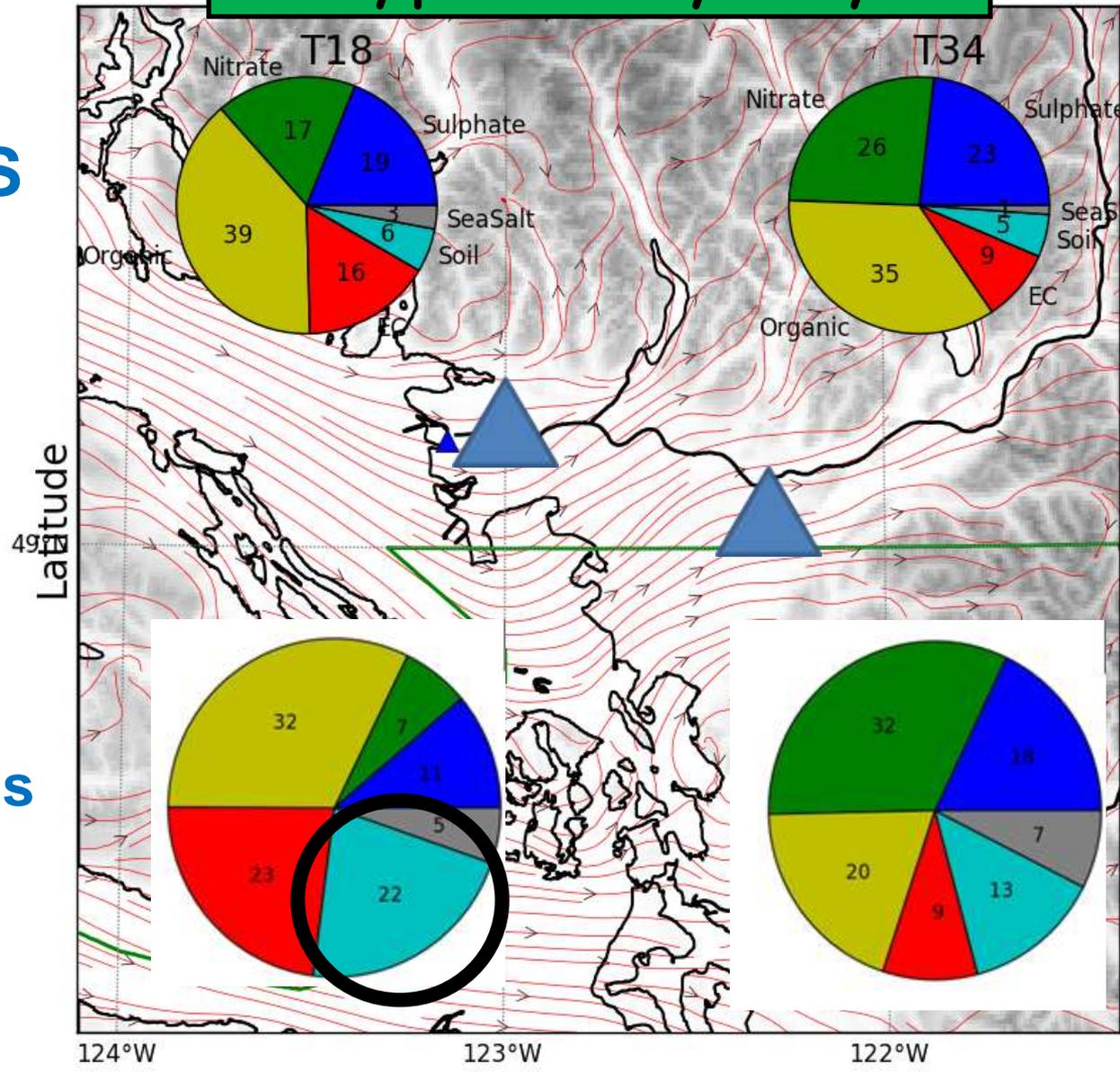
Aurams
T34

Longitude

Typical Key Day

**NAPS
T18**

**NAPS
T34**



**Aurams
T18**

**Aurams
T34**

Longitude

Summary - Exercising the model II

Model speciation responsive to changing episodic conditions

Model does not always correctly reproduce PM_{2.5} speciation

Is model ready for policy runs?

(e.g. what level of agreement is sufficient?)

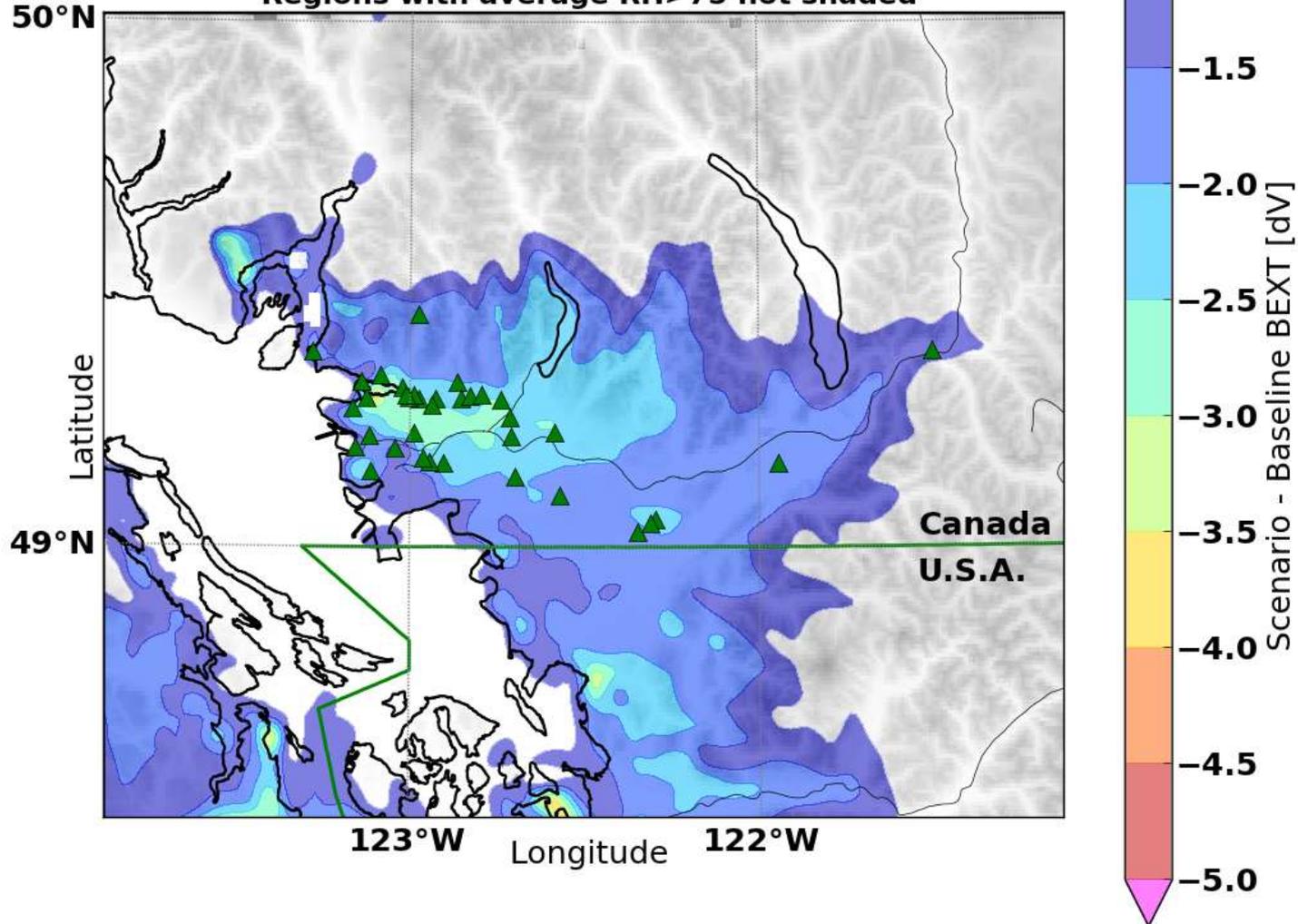
How do we control for RH-variability?

Results

How do the same emissions reductions impact extinction under the different meteorological regimes?

OM-day (June 2006) 50% Emissions reductions

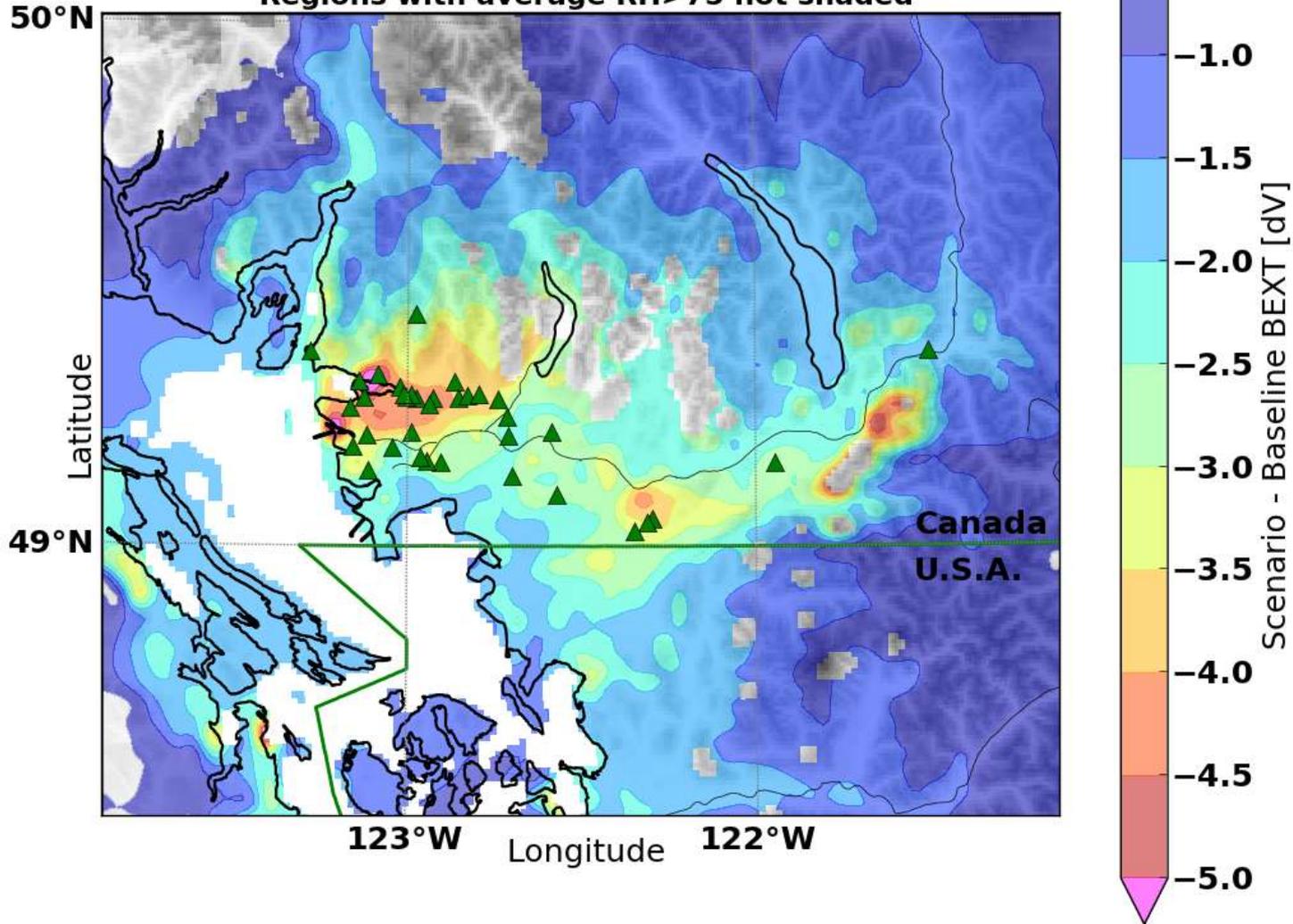
June 2006 Avg (1200-1900 PST) BEXT [dV] under ALL %50 scenario
Regions with average RH > 75 not shaded



Sulphate day (August 2007)

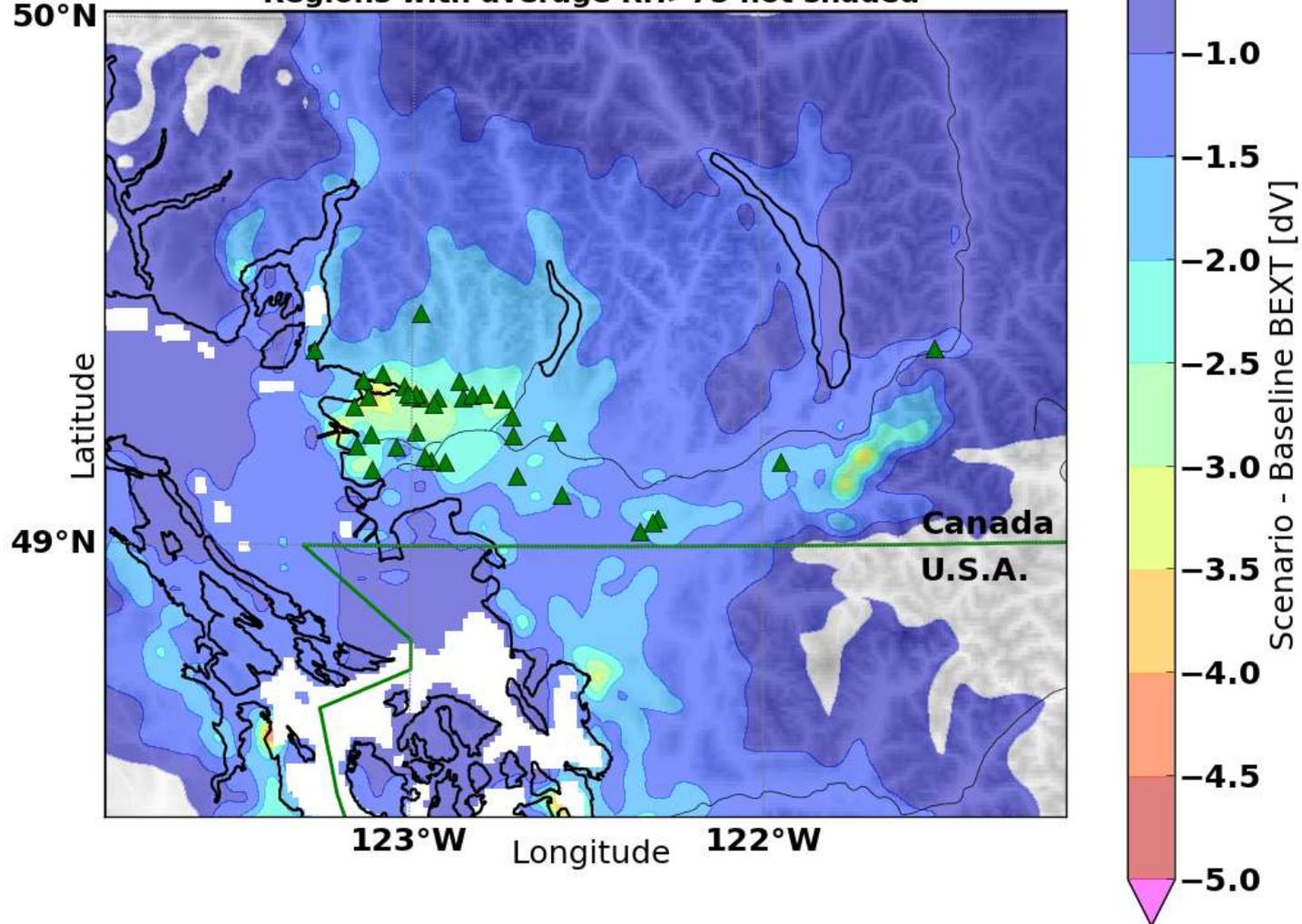
50% Emissions reductions

Aug 2007 Avg (1200-1900 PST) BEXT [dV] under ALL %50 scenario
Regions with average RH>75 not shaded



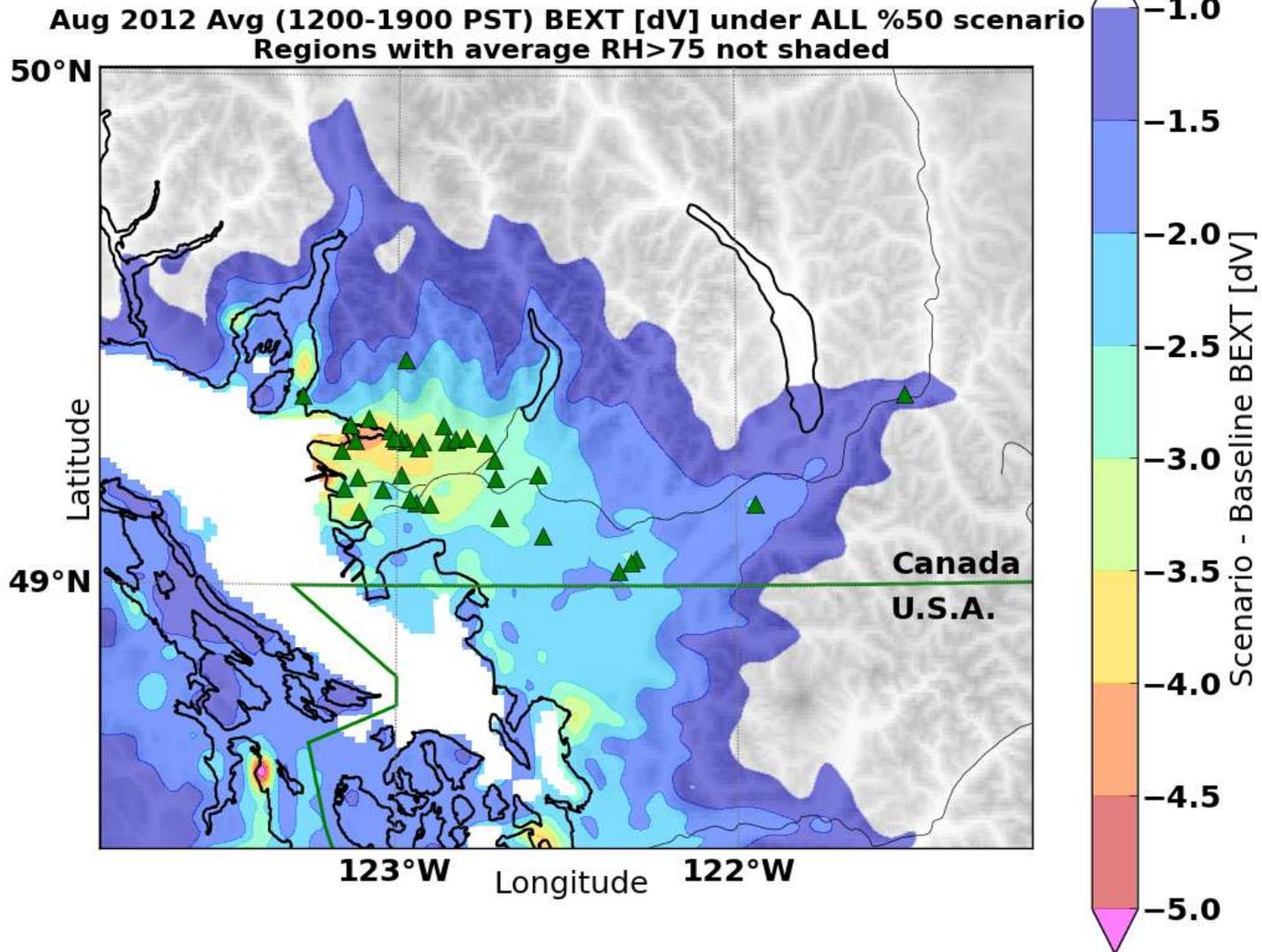
Typical-day (Sep 2012) 50% Emissions reductions

Sep 2012 Avg (1200-1900 PST) BEXT [dV] under ALL %50 scenario
Regions with average RH > 75 not shaded



Ozone episode (August 2012)

50% Emissions reductions



Discussion:

What causes the day-to-day
speciation variability?

Emissions variability?

→ Weekend vs. Weekday emissions,
increased biogenic & evaporative under
warmer temperatures

Meso-scale meteorological variability?

→ Different wind patterns set up
specific source-receptor relationships

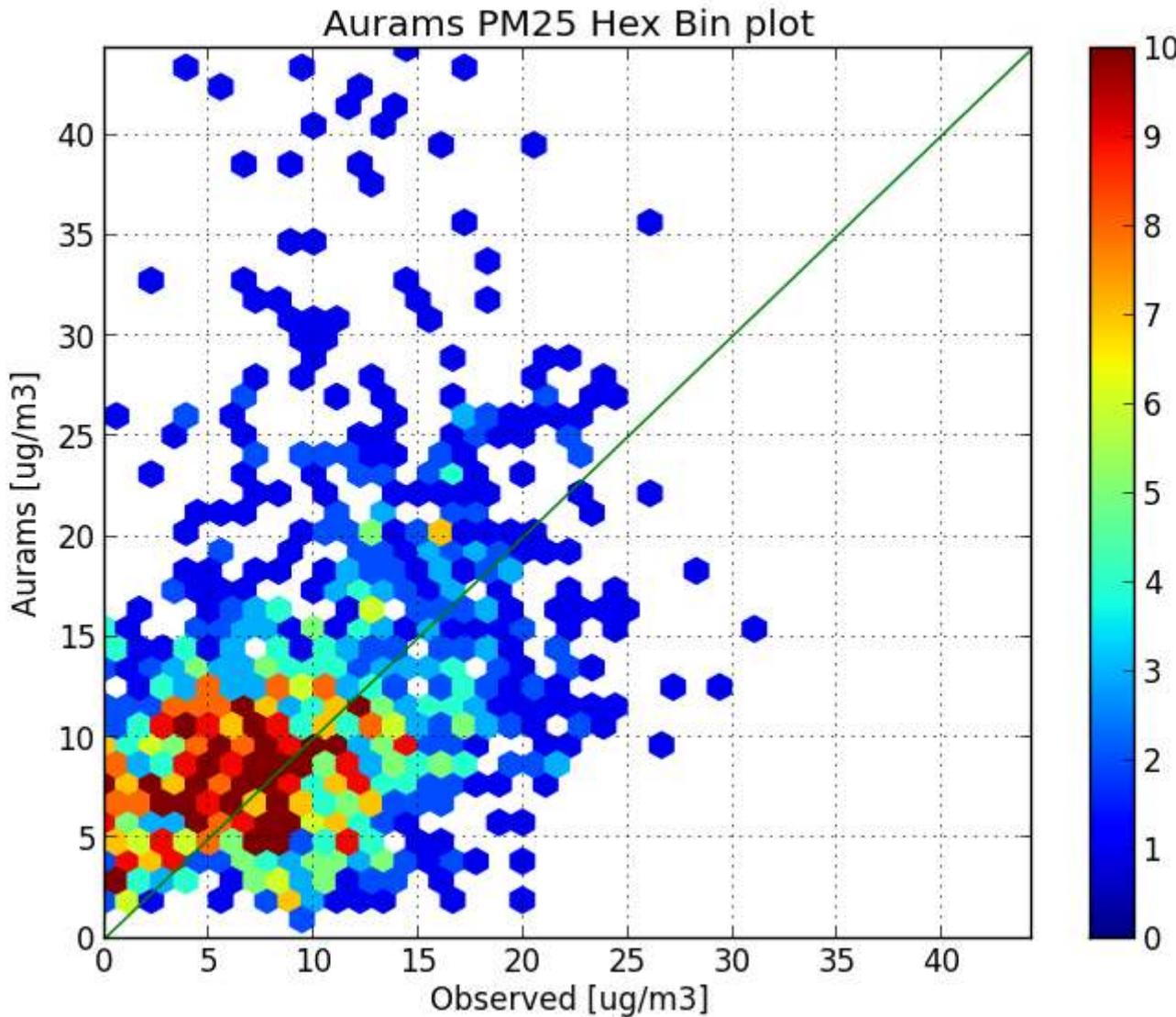
Chemical variability?

→ Different chemical pathways under
high/low RH, high/low temperature

QUESTIONS?



August 2012 PM25 comparison (1463 Observation-model pairs)



RMSE	7.3	ug/m3
MAE	5.4	ug/m3
NMAE	58.9	%
MBE	-2.0	ug/m3
NMBE	-21.4	%
R2	0.39	-