Developing Geospatial Models for Exposure Assessment in Windsor, ON

An Evolution - Land Use Regression to Hybrid Models

Presented by
Alice Grgicak-Mannion
Great Lakes Institute for Environmental Research
University of Windsor
October 29th, 2008

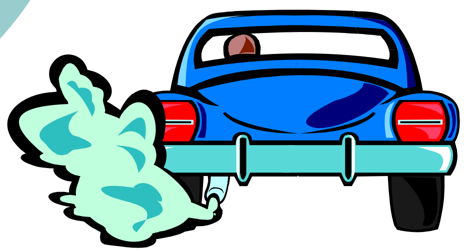
“Place” and “Location” Play Important Role in Determining Exposure

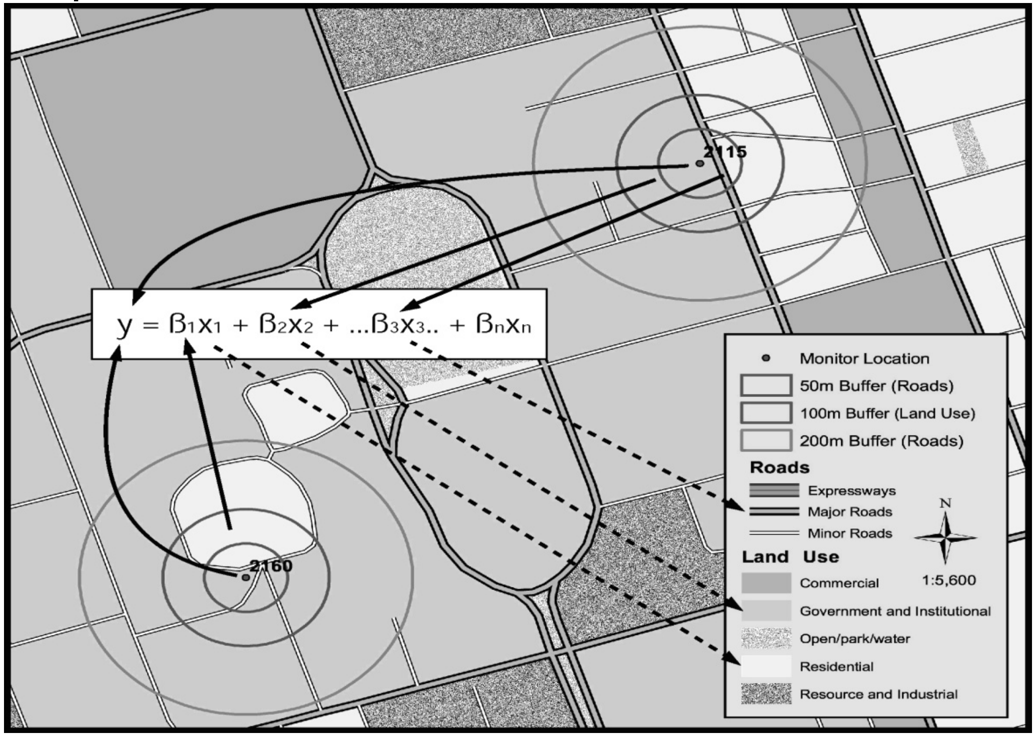
- **Linking health status to one’s geography/environment IS IMPORTANT**
  - **what do I live near? (water, air, industry, etc.)**
  - **Do living next to these geographic and urban features affect me and my health?**
- **Can we change “places” to reduce exposure? (Prevention)**
- **Can this information be helpful to my doctor and/or to my community?**

Land Use Regression

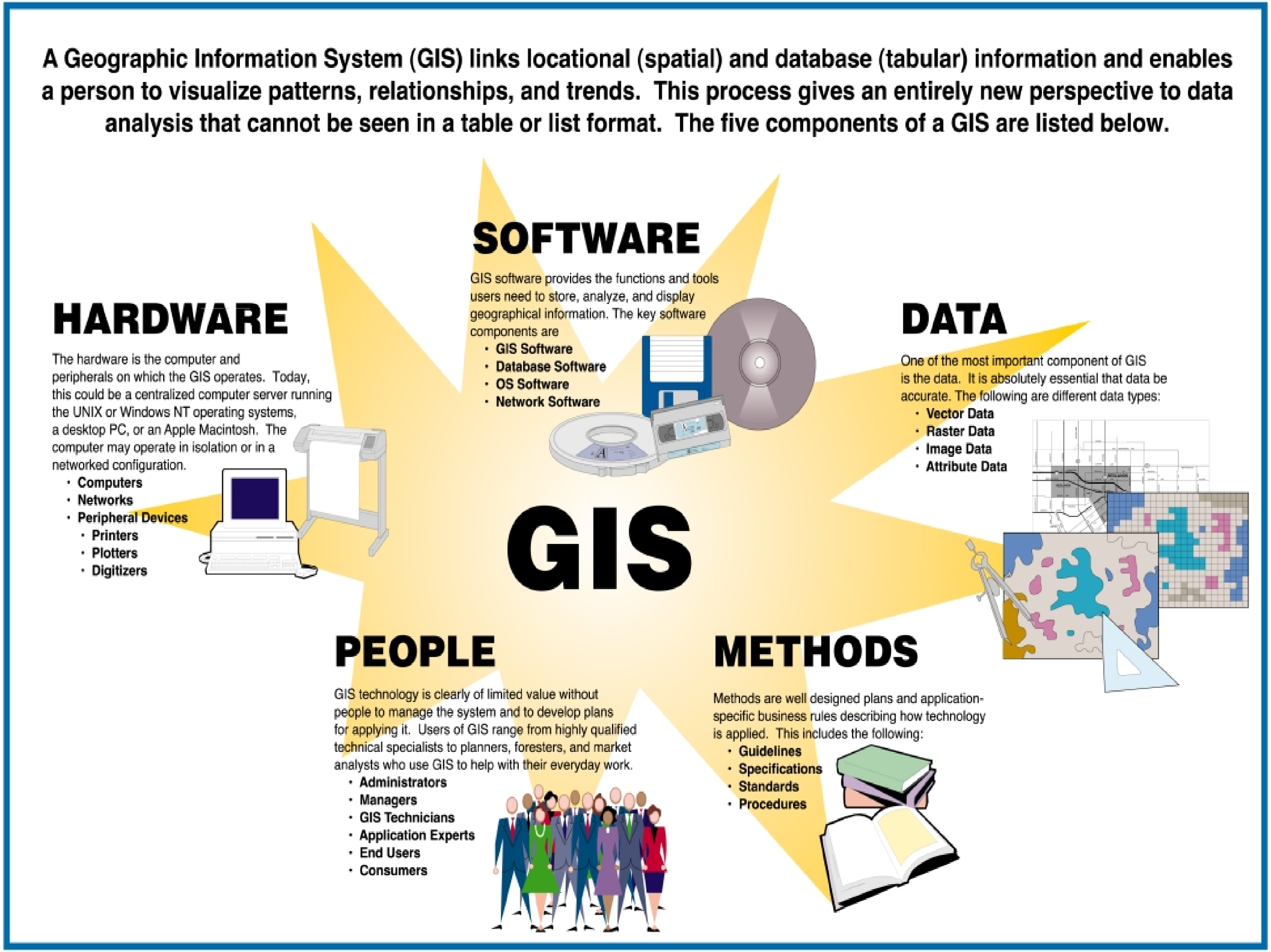
○ What is LUR?

- A response variable (e.g. NO_2 concentration) is measured against a group of predictor variables (traffic, land use, population, etc.) to determine the extent of their relationship





Source: Jerrett, M., Arain, M. A., Kanaroglou, P., Beckerman, B., Crouse, N., Gilbert, N. L., Brook, J. R. and Finkelstein, N. 2003. Modelling the intra-urban variability of ambient traffic pollution in Toronto, Canada. In *Strategies for Clean Air and Health* (Proceedings of AIRNET Annual Conference/ NERAM International Colloquium) L. Craig, D. Krewski, J. Shortreed, and J. Samet (Eds). pp. 19-34.



Source:ESRI Inc., 2007

Objectives

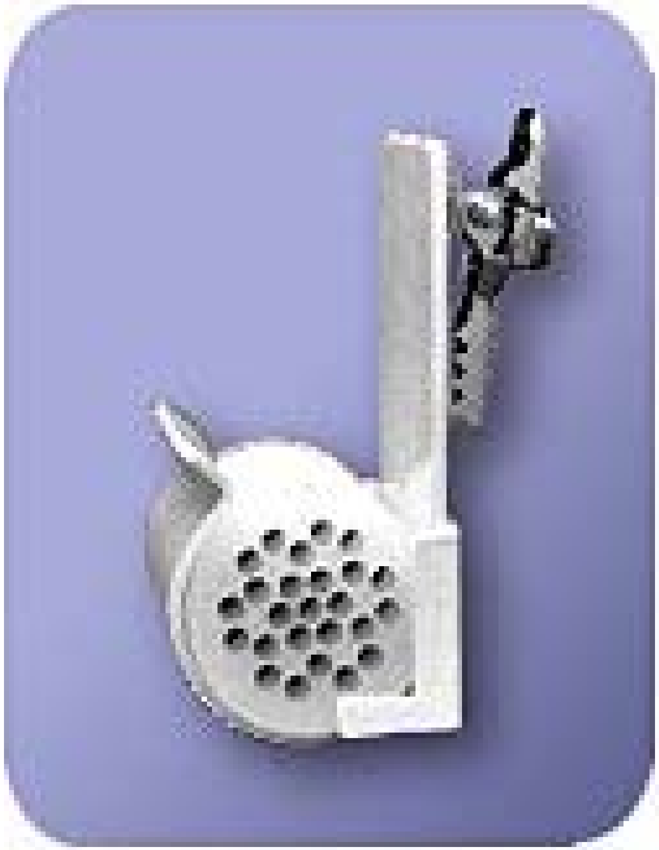
- As part of the Border Air Quality Strategy, this study focused on the development of multi season, multiyear geospatial land use regression (LUR) models for NO_2 ,$PM_{2.5}$ and BTEX (Benzene, Toluene, Ethylbenzene and Xylene) for Windsor, ON.
- **The main objective was to determine whether regression results were consistent from season to season and whether similar trends could be seen from year to year.**

Methodology

- 50 Active and Passive samples were taken of each pollutant over a two-week period in February, May, August and October for the years 2004 and 2005.
- Predictor variables, i.e. high resolution geospatial land-use and traffic variables were generated using Geographic Information Systems (GIS).
- Step-wise regression statistics were used to determine the predictor variables for each model.

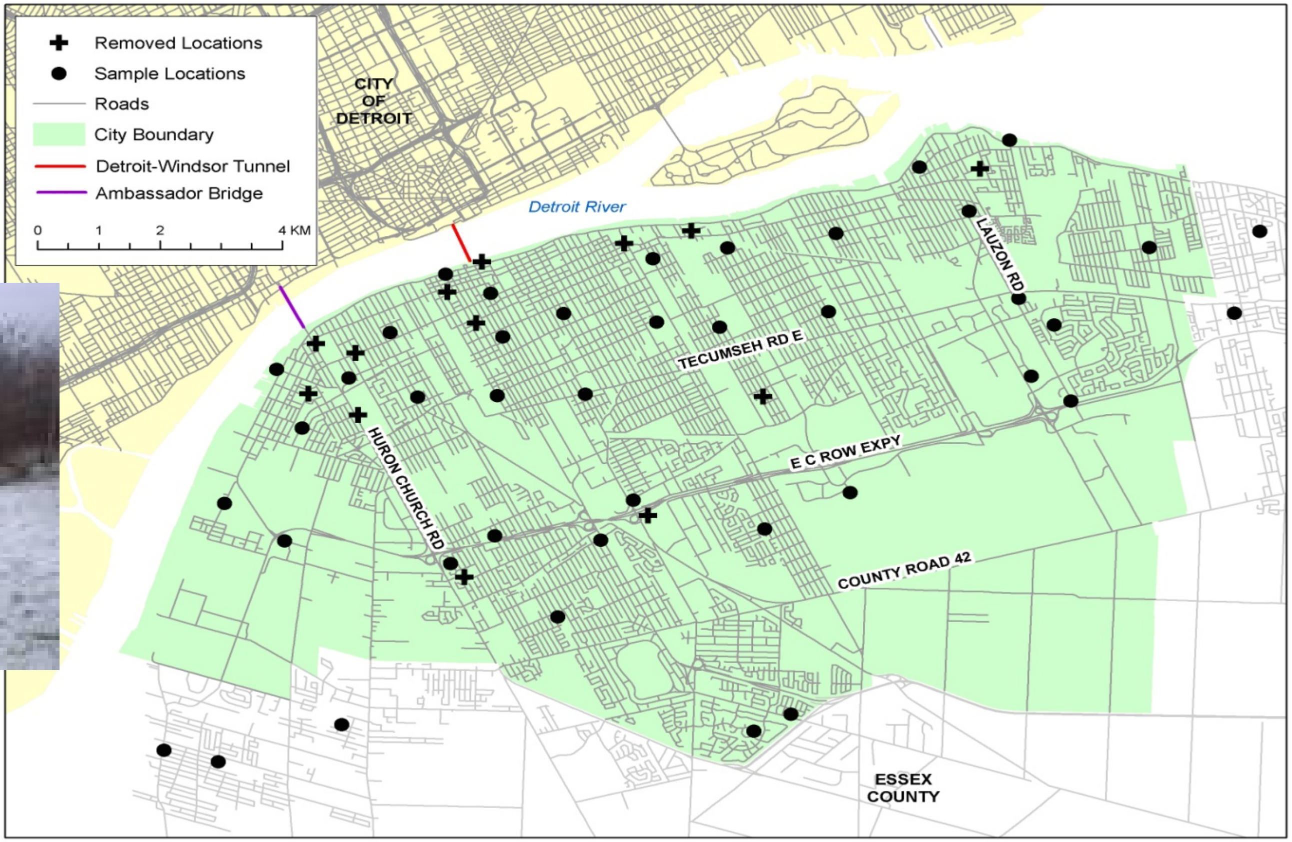
Methodology

- Monitors



Methodology

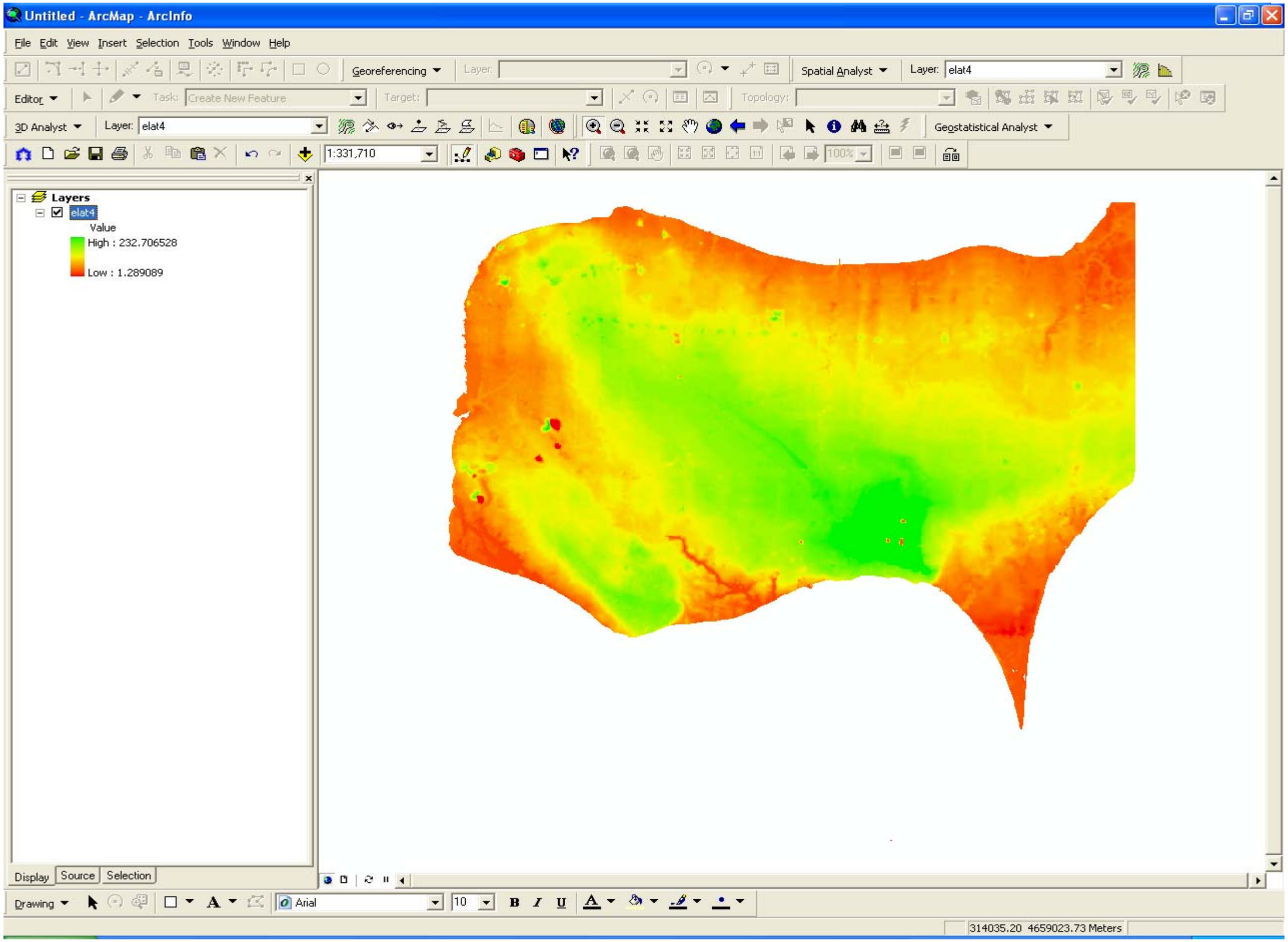
- Study Area with Sites (50 locations = GPS)



Databases Created/Used

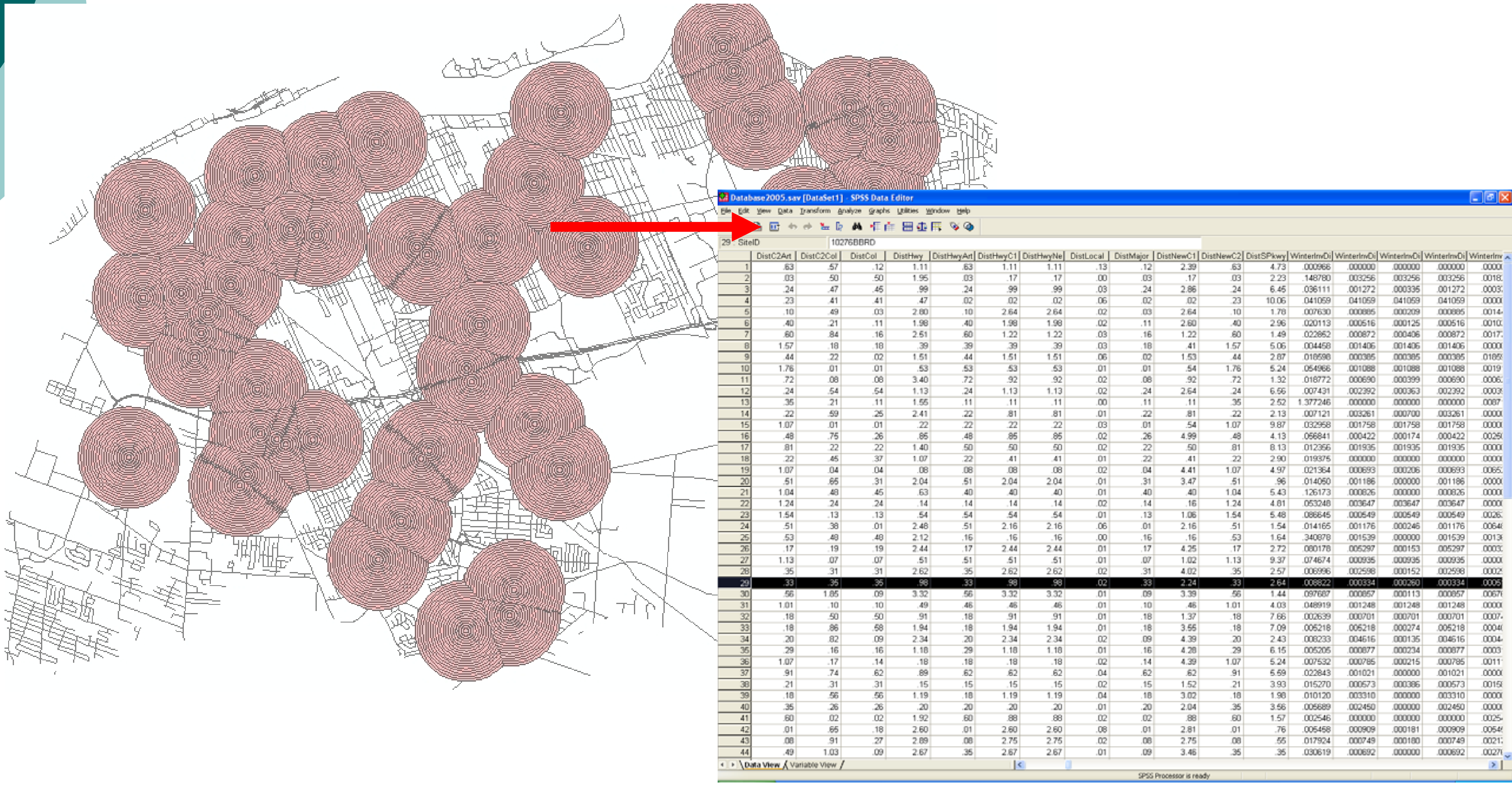
- Data Provided by the City of Windsor
  - Traffic Counts (TMC, AM, PM, Truck)
  - Land use Information (parcel)
  - Skeletal Road Layer
- Census Data by Statistics Canada
  - Dwelling and Population Counts
- Wind Direction Data by Environment Canada
- Topographic Data
  - Easting, northing, elevation
- Similar data provided by the Towns of Tecumseh, LaSalle and Essex
- International Data by SEMCOG
  - Detroit Road, Traffic and Land use

Converting Data into a Geospatial Format



Buffering

- ArcGIS and SPSS



SPSS & Stepwise Regression

NO2Average.SPS - SPSS Syntax Editor

```
REGRESSION
 /MISSING PAIRWISE
 /STATISTICS COEFF OUTS R ANOVA
 /CRITERIA=PIN(.10) POUT(.15)
 /NOORIGIN
 /DEPENDENT NO2_Average
 /METHOD=STEPWISE northing elevation DistArt DistBridge
 DistC1ArtNewC2Art DistC1Col DistC2Art DistC2Col DistCol DistHwy
 DistHwyArt DistHwyC1Art DistHwyNewC1Art DistMajor DistNewC1Art
 DistNewC2Art DistSPkwy
 All_Area_1000 All_Area_950 All_Area_900
 All_Area_500 All_Area_450 All_Area_400 All_Area_350 All_Area_300
 All_Area_250 All_Area_200 All_Area_150 All_Area_50
 All_Length_500 All_Length_450 All_Length_400 All_Length_350 All_Length_300
 All_Length_250 All_Length_200 All_Length_50
 Local_Area_950 Local_Area_900 Local_Area_850 Local_Area_800
 Local_Area_750 Local_Area_700 Local_Area_650
 Local_Area_350 Local_Area_300
 Local_Area_250 Local_Area_200 Local_Area_150 Local_Area_100 Local_Area_50
 Local_Length_950 Local_Length_900 Local_Length_850
 Local_Length_800 Local_Length_750 Local_Length_700 Local_Length_650
 Local_Length_350 Local_Length_300 Local_Length_250
 Local_Length_200 Local_Length_150 Local_Length_100 Local_Length_50
 Art_Area_1000 Art_Area_950 Art_Area_900 Art_Area_850 Art_Area_800
 Art_Area_750 Art_Area_700 Art_Area_650 Art_Area_600 Art_Area_550
 Art_Area_500 Art_Area_450 Art_Area_400 Art_Area_350 Art_Area_300
 Art_Length_1000 Art_Length_950 Art_Length_900 Art_Length_850 Art_Length_800
 Art_Length_750 Art_Length_700 Art_Length_650 Art_Length_600 Art_Length_550
 Art_Length_500 Art_Length_450 Art_Length_400 Art_Length_350 Art_Length_300
 Art_AM_1000 Art_AM_950 Art_AM_900
 Art_AM_600 Art_AM_550 Art_AM_500 Art_AM_450 Art_AM_400
 Art_AM_350 Art_AM_300 Art_PM_1000 Art_PM_950
 Art_PM_600 Art_PM_550 Art_PM_500
 Art_PM_450 Art_PM_400 Art_PM_350 Art_PM_300 Art_Truck_1000 Art_Truck_950
 Art_Truck_900 Art_Truck_850 Art_Truck_800 Art_Truck_750 Art_Truck_700
 Art_Truck_650 Art_Truck_600 Art_Truck_550 Art_Truck_500 Art_Truck_450
 Art_Truck_400 Art_Truck_350 Art_Truck_300 Art_Traffic_1000 Art_Traffic_950
 Art_Traffic_900
 Art_Traffic_600 Art_Traffic_550
 Art_Traffic_500 Art_Traffic_450 Art_Traffic_400 Art_Traffic_350
 Art_Traffic_300 C1ArtNewC2Art_Area_1000 C1ArtNewC2Art_Area_950
 C1ArtNewC2Art_Area_900 C1ArtNewC2Art_Area_850 C1ArtNewC2Art_Area_800
 C1ArtNewC2Art_Area_750 C1ArtNewC2Art_Area_700 C1ArtNewC2Art_Area_650
 C1ArtNewC2Art_Area_600 C1ArtNewC2Art_Area_550 C1ArtNewC2Art_Area_500
 C1ArtNewC2Art_Area_450 C1ArtNewC2Art_Area_400 C1ArtNewC2Art_Area_350
 C1ArtNewC2Art_Area_300 C1ArtNewC2Art_Length_1000 C1ArtNewC2Art_Length_950
 C1ArtNewC2Art_Length_900 C1ArtNewC2Art_Length_850 C1ArtNewC2Art_Length_800
 C1ArtNewC2Art_Length_750 C1ArtNewC2Art_Length_700 C1ArtNewC2Art_Length_650
 C1ArtNewC2Art_Length_600 C1ArtNewC2Art_Length_550 C1ArtNewC2Art_Length_500
 C1ArtNewC2Art_Length_450 C1ArtNewC2Art_Length_400 C1ArtNewC2Art_Length_350
 C1ArtNewC2Art_Length_300 C1ArtNewC2Art_AM_1000
 C1ArtNewC2Art_AM_450 C1ArtNewC2Art_AM_400 C1ArtNewC2Art_AM_350
 C1ArtNewC2Art_AM_300
 C1ArtNewC2Art_PM_450 C1ArtNewC2Art_PM_400
 C1ArtNewC2Art_PM_300 C1ArtNewC2Art_Truck_1000 C1ArtNewC2Art_Truck_950
 C1ArtNewC2Art_Truck_900 C1ArtNewC2Art_Truck_850 C1ArtNewC2Art_Truck_800
```

SPSS Processor is ready | Ln 1 Col 1 | NUM

Output1 - SPSS Viewer

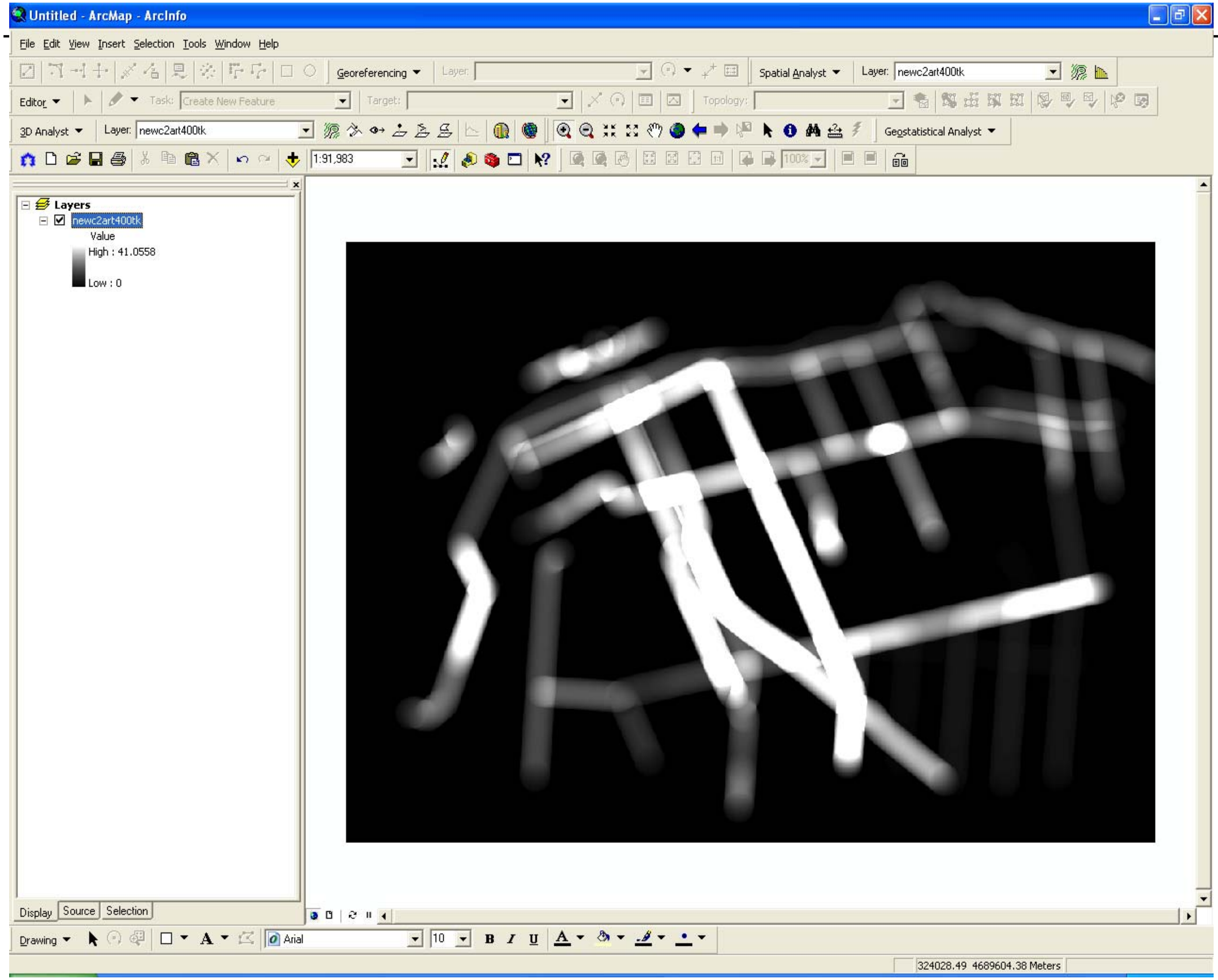
Output
- Regression
  - Title
  - Notes
  - Active Dataset
  - Variables Entered/Removed
  - Model Summary
  - ANOVA
  - Coefficients
  - Excluded Variables

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	17.657	.701		25.175	.000
	DistBridge	-.548	.090	-.768	-6.112	.000
2	(Constant)	16.596	.549		30.241	.000
	DistBridge	-.474	.066	-.664	-7.136	.000
	Major_Truck_150	.307	.061	.465	4.996	.000
3	(Constant)	17.312	.355		48.784	.000
	DistBridge	-.477	.041	-.668	-11.693	.000
	Major_Truck_150	.263	.038	.399	6.870	.000
	Open150	-1.000	.154	-.368	-6.494	.000
4	(Constant)	16.746	.350		47.821	.000
	DistBridge	-.450	.036	-.630	-12.589	.000
	Major_Truck_150	.211	.036	.320	5.803	.000
	Open150	-.927	.133	-.341	-6.975	.000
	Art_AM_300	.061	.019	.182	3.188	.004
5	(Constant)	16.048	.331		48.414	.000
	DistBridge	-.413	.030	-.578	-13.812	.000
	Major_Truck_150	.224	.029	.340	7.730	.000
	Open150	-.900	.105	-.331	-8.528	.000
	Art_AM_300	[illegible]	.015	.187	4.123	.000
	Industrial1000	.021	.005	[illegible]	3.837	.001
6	(Constant)	16.058	.177		90.481	.000
	DistBridge	-.340	.019	-.476	-18.124	.000
	Major_Truck_150	.213	.016	.322	13.609	.000
	Open150	-.863	.057	-.317	-15.230	.000
	Art_AM_300	.066	.008	.197	8.102	.000
	Industrial1000	.037	.004	.269	10.191	.000
	DistNewC1Art	-.424	.057	-.200	-7.467	.000

Pivot Table is visible | SPSS Processor is ready | H: 5721 , W: 438 p

Predictor Layers Developed



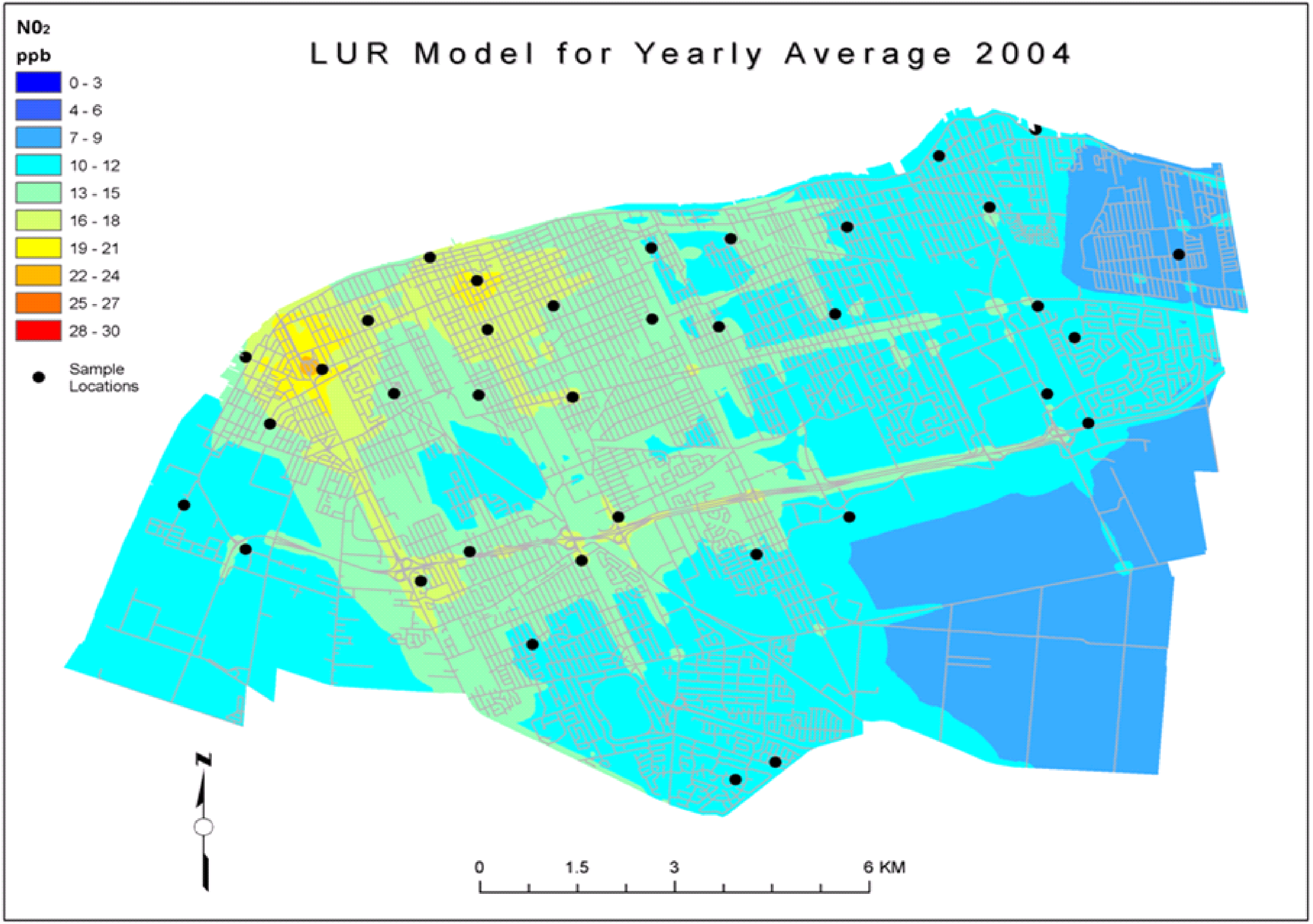
Results and Model Maps

- The 2004 seasonal LUR results for NO_2 were $R^2 = 0.898$ for February, $R^2 = 0.421$ for May, $R^2 = .821$ for August , $R^2 = .0.742$ for October.
- The 2004 yearly model resulted in an R^2 of 0.917.
- Several reoccurring variables (i.e. Distance to Bridge, Dwelling Count, Open Area, etc.) were found in multiple models.

Results and Model Maps

Model for Yearly Avg. 2004	*Unstd Coef*		*Std Coef*	*t*	*Sig.*	*Adj. R Sq*
	B	*Std. Error*	*Beta*			
Model 5 (Constant)	10.689	0.429		24.904	0	
Distance to Bridge	-0.232	0.034	-0.399	-6.92	0	
DwellCount@800M	0.001	0	0.448	8.792	0	
Ma-jor_Trucks@1000M	0.013	0.002	0.348	6.57	0	
Major_PM@150M	0.083	0.016	0.236	5.063	0	
DistanceALLRoads	-15.717	5.472	-0.139	-2.872	0.007	**0.917**

Results and Model Maps



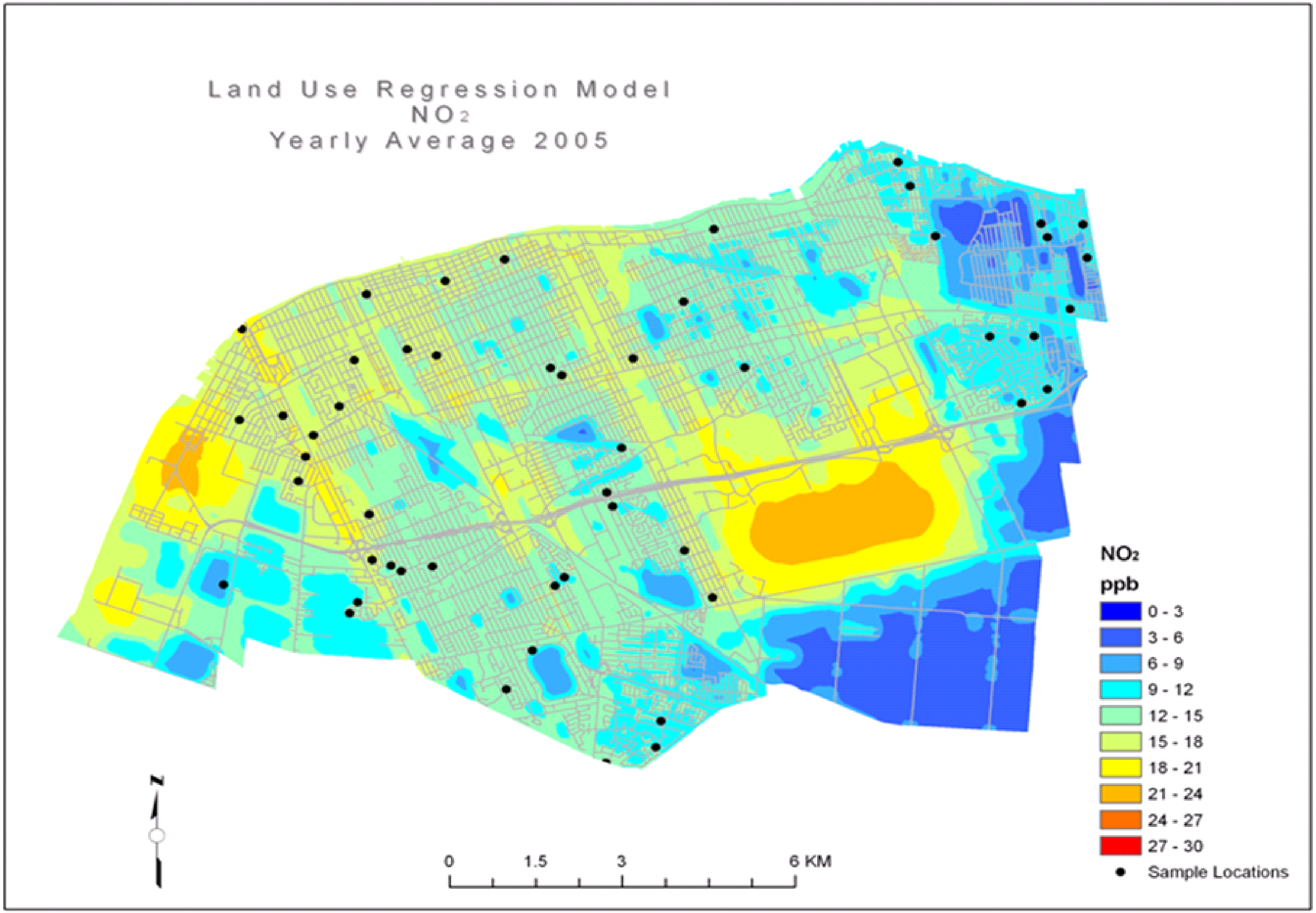
Results and Model Maps

- **The NO_2 seasonal results for 2005 were R^2 = .794 for February, R^2 = .632 for May, R^2 = .908 for August, R^2 = .941 for October and an R^2 of .939 for the yearly average**
- **Only two reoccurring variables stood out in 2005, they were Distance to Bridge and Industrial.**
- **The PM 2.5 and BTEX models were not as consistent as NO_2. 2004 and 2005 BTEX R^2 values ranged from .356 to .779 and .649 to .940, respectively. PM 2.5 2005 R^2 values ranged from .131 (see Figure 12 & 13) to .960.**

Results and Model Maps

Model for Yearly Avg. 2005	*Unstd Coef*		*Std Coef*	*t*	*Sig.*	*Adj. R Sq*
	B	*Std. Er-ror*	*Beta*			
Model 4 (Constant)	16.746	0.35		47.821	0	
Distance to Bridge	-0.45	0.036	-0.63	-12.59	0	
Major_Truck_150	0.211	0.0336.26	0.32	5.803	0	
Open150	-0.927	0.133	-0.341	-6.975	0	
Art_AM_300	0.061	0.019	0.182	3.188	0.004	**0.939**

Results and Model Maps



Conclusion/Discussion

- Overall, 2004 models performed reasonably well, while the 2005 models experienced some multicollinearity and overprediction.
- Sampling site locations and land use misclassification (e.g. Industrial vs. Open Area) may have played a role as well.

Conclusion/Discussion

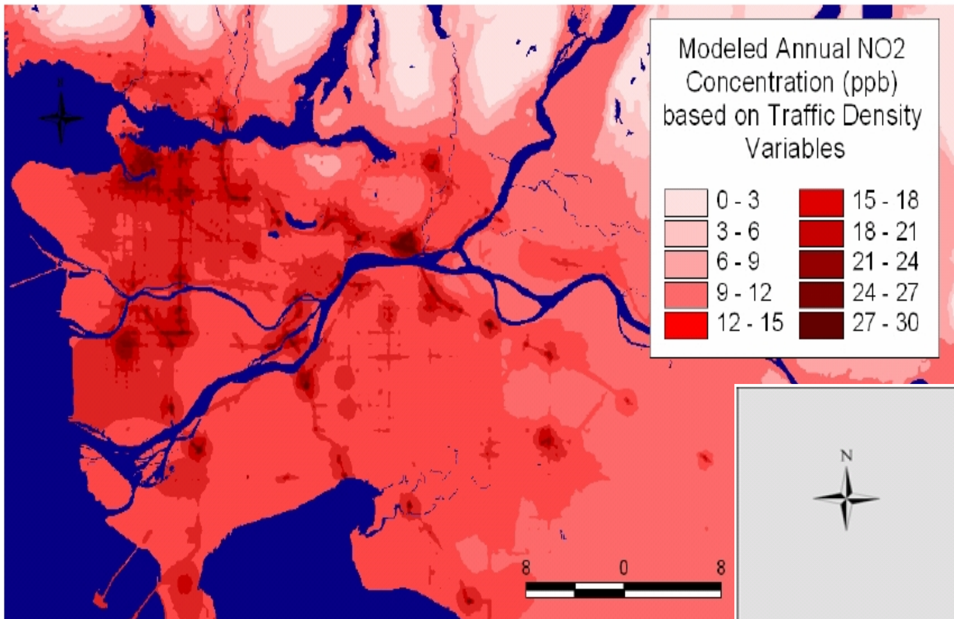
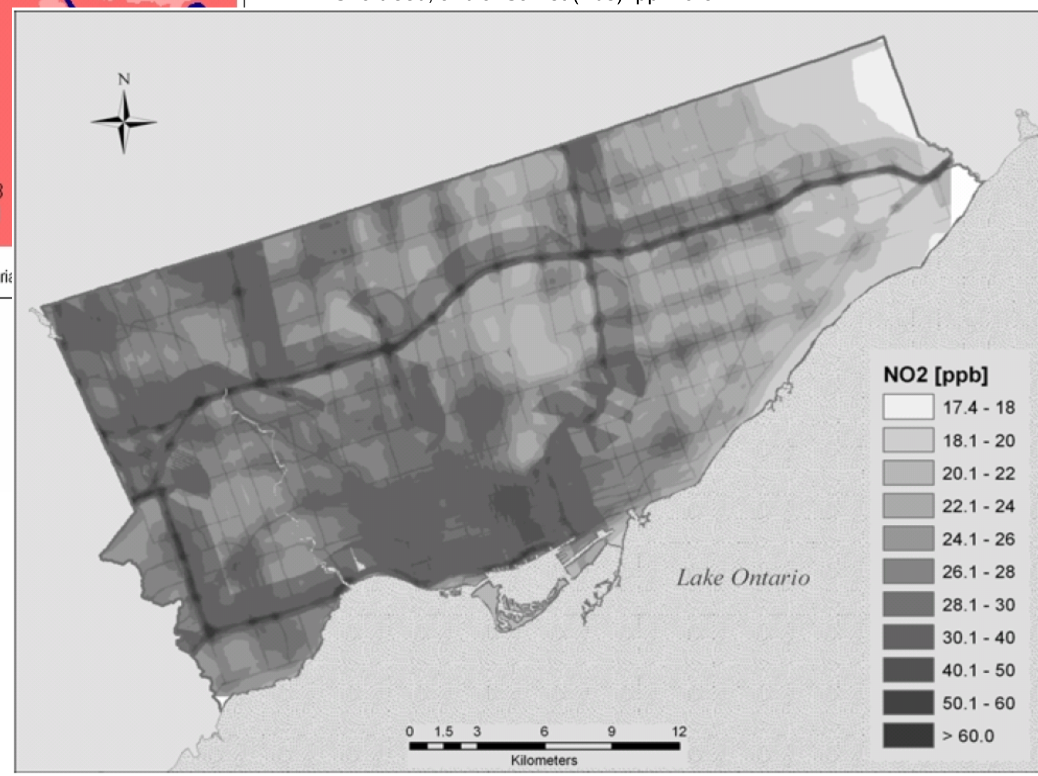


Figure 4.12. Result of the final regression surface for NO_2 built with traffic density varia

Source: Henderson, S. and Brauer, M. 2005. Measurement and Modelling of traffic related air pollution in the British Columbia lower mainland for use in health risk assessment and epidemiological analyses. Report pp. 40.

Source: Jerrett, M., Arain, M. A., Kanaroglou, P., Beckerman, B., Crouse, N., Gilbert, N. L., Brook, J. R. and Finkelstein, N. 2003. Modelling the intra-urban variability of ambient traffic pollution in Toronto, Canada. In *Strategies for Clean Air and Health* (Proceedings of AIRNET Annual Conference/ NERAM International Colloquium) L. Craig, D. Krewski, J. Shortreed, and J. Samet (Eds). pp. 19-34.



Acknowledgements

- Dr. Iris Xu
- Dr. Amanda Wheeler
- Mr. Jason Wintermute
- Dr. Jeff Brook
- Dr. Issac Luginaah

Acknowledgements

- We gratefully acknowledge the funding support of Health Canada. We would like to thank the City of Windsor's GIS Division, Public Works Department and Planning Department for providing geospatial data pertinent to this study.
- In particular, we would like to thank Jennifer Escott, Marian Drouillard, Steve Bittner, and Waqar Syed for being accessible to answer any of our questions throughout this project.
- Other municipalities we would like to thank are: Town of Tecumseh, Town of LaSalle, the Corporation for the County of Essex and South Eastern Michigan Council of Governments (SEMCOG) for allowing the use of their geospatial information.

What is next?
Potential Hybrid Models in Windsor

- **Remote Sensing**
  - It is "*the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.*"

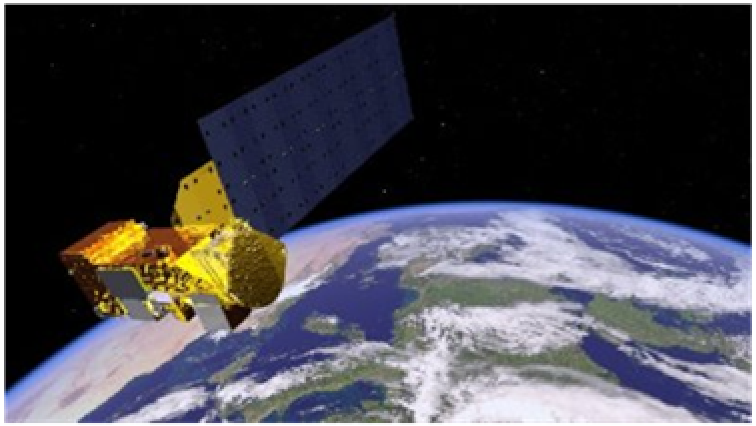
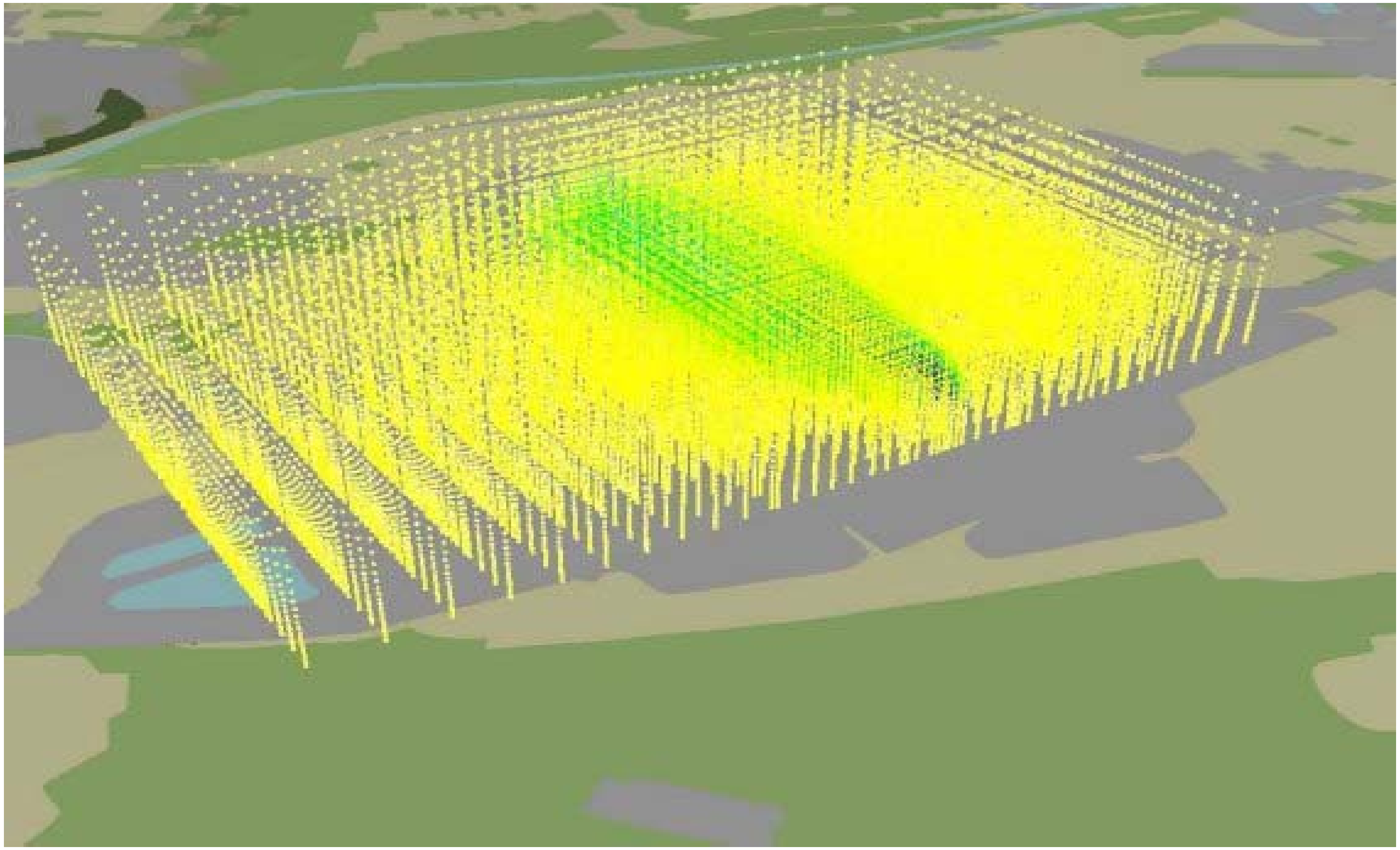


Image by NASA. Computer rendition of NASA's Aqua satellite, launched May 4, 2002.

Air pollution on a grand scale is often easily visible from space. An imposing example is the mixture of smoke and smog created by fires spread over many islands in Indonesia. Using imagery acquired by TOMS, and set against a backdrop developed from NOAA data, a huge smoke plume (white), mixed with smog (colors represent variations in ozone amounts) is seen to be heading westward from the islands across the Indian Ocean.

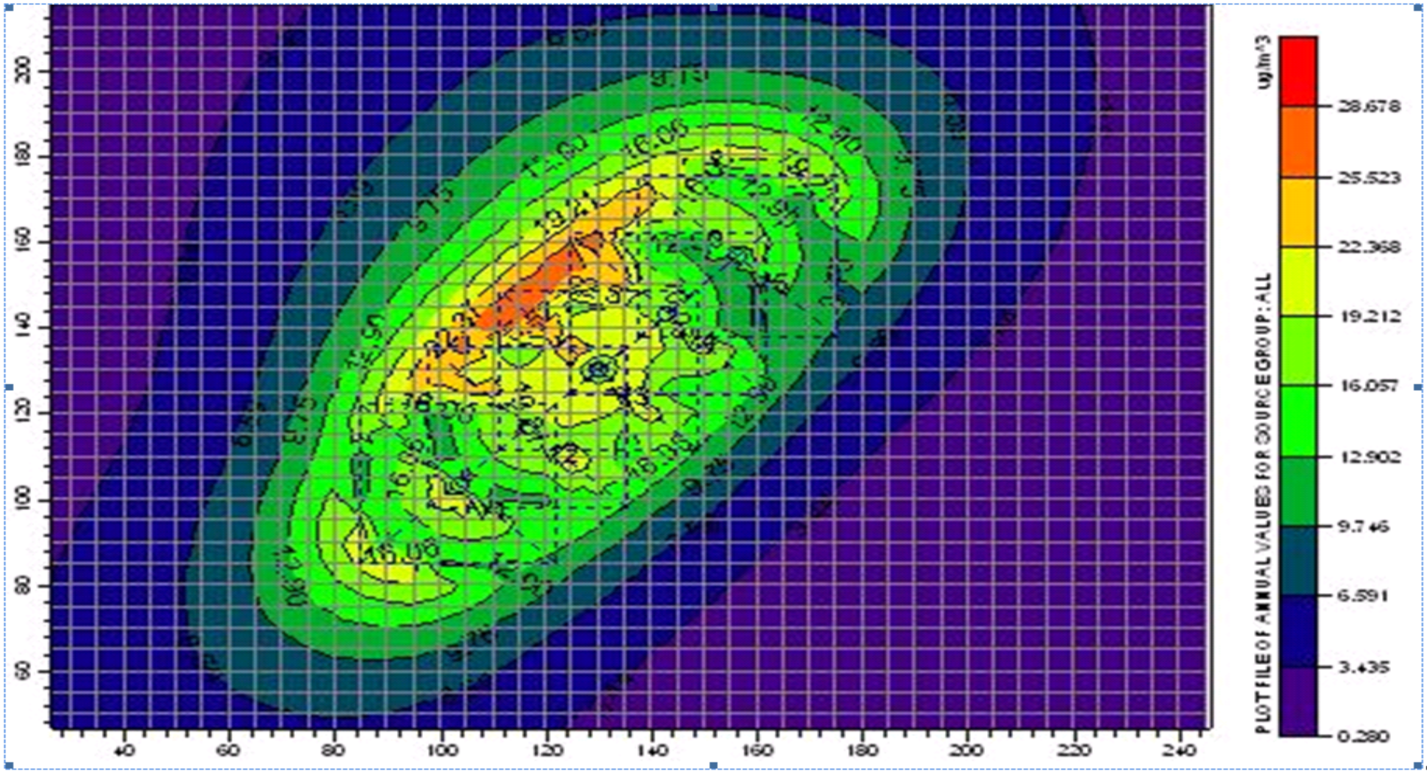
What is next?
Potential Hybrid Models in Windsor

- **Regional Level and Vertical Models using Sensor Networks**

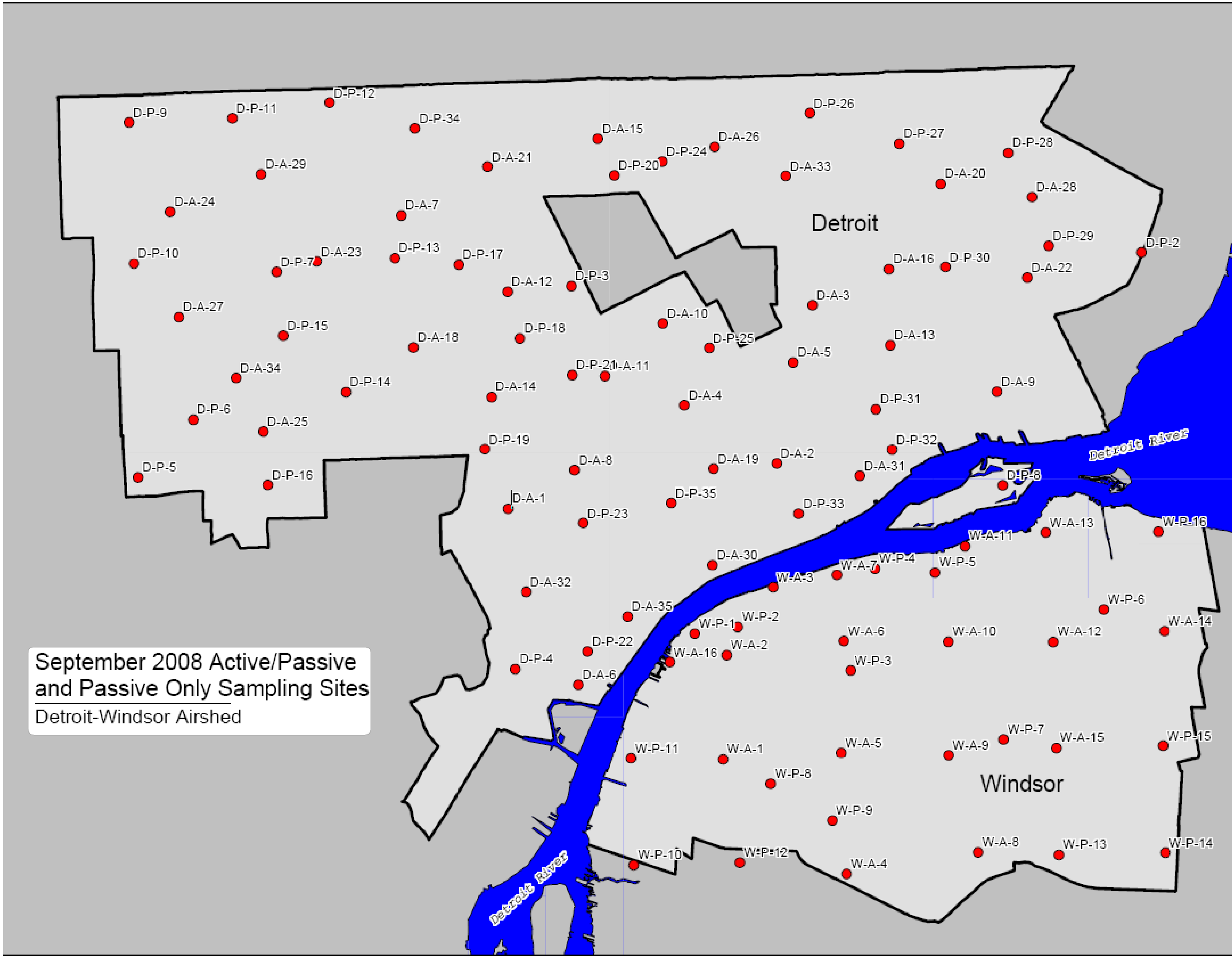


What is next?
Potential Hybrid Models in Windsor

- **Dispersion Models (Dr. Iris Xu) combined with LUR**



Using separated volume sources to represent a line source


September 2008 Active/Passive
and Passive Only Sampling Sites
Detroit-Windsor Airshed
Detroit
Windsor
Detroit River
Detroit River
D-P-9
D-P-11
D-P-12
D-P-34
D-A-15
D-A-26
D-P-24
D-P-20
D-A-21
D-A-29
D-A-24
D-A-7
D-P-26
D-P-27
D-P-28
D-A-33
D-A-20
D-A-28
D-P-29
D-P-2
D-P-10
D-P-7
D-A-23
D-P-13
D-P-17
D-A-12
D-P-3
D-A-16
D-P-30
D-A-22
D-A-3
D-A-27
D-P-15
D-A-18
D-P-18
D-A-10
D-P-25
D-A-13
D-A-5
D-A-34
D-P-14
D-A-14
D-P-21
D-A-11
D-A-4
D-A-9
D-P-31
D-P-6
D-A-25
D-P-19
D-P-32
D-A-8
D-A-19
D-A-2
D-A-31
D-P-8
D-P-5
D-P-16
D-A-1
D-P-35
D-P-23
D-P-33
W-A-13
W-P-16
W-A-11
D-A-30
W-A-7
W-P-4
W-P-5
W-A-3
D-A-32
W-P-6
D-A-35
W-P-1
W-P-2
W-A-14
W-A-6
W-A-10
W-A-12
D-P-22
W-A-2
D-P-4
W-A-16
W-P-3
D-A-6
W-P-7
W-A-15
W-P-15
W-P-11
W-A-1
W-A-5
W-A-9
W-P-8
W-P-9
W-A-8
W-P-13
W-P-14
W-P-10
W-P-12
W-A-4

What else are we up to? Isoscapes

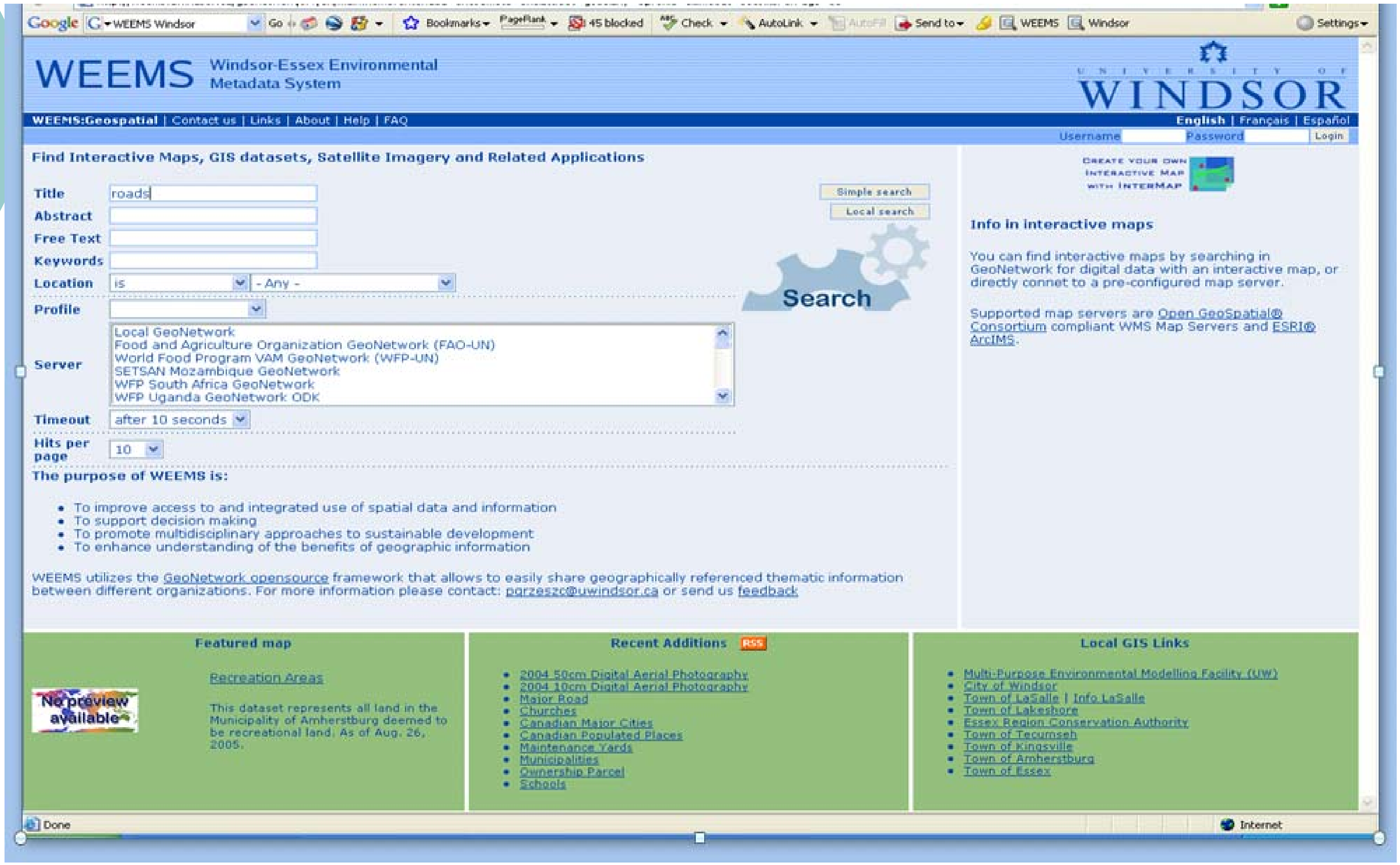
- **Isoscapes** (**iso**tope land**scapes**) are spatially explicit predictions of stable isotope ratios based on:
- ►Process-level mathematical models
- ►Spatial model execution in Geographic Information Systems (GIS)
- Looking to take 100+ samples (grass and vegetation) across Windsor ON to determine signatures and correlations to traffic and road dust
- Wesley Moga, Dr. Aaron Fisk and A. Grgicak-Mannion

What else are we up to? Magnetic Signatures (Potential)

- Magnetic susceptibility mapping to track air pollution and particulate matter and it combining health parameter data
- Dr. Maria Cioppa (PI)

What else are we up to?

Windsor-Essex Environmental Metadata System (WEEMS)



THANK YOU !!!!

Contact Information:

Alice Grgicak-Mannion
Geospatial Learning Specialist / GLIER Researcher
Great Lakes Institute for Environmental Research
University of Windsor
401 Sunset Ave.
Windsor, ON CANADA
N9B 3P4

p. 519-253-3000 ext. 2170
f. 519-971-3616
e-mail. grgica3@uwindsor.ca