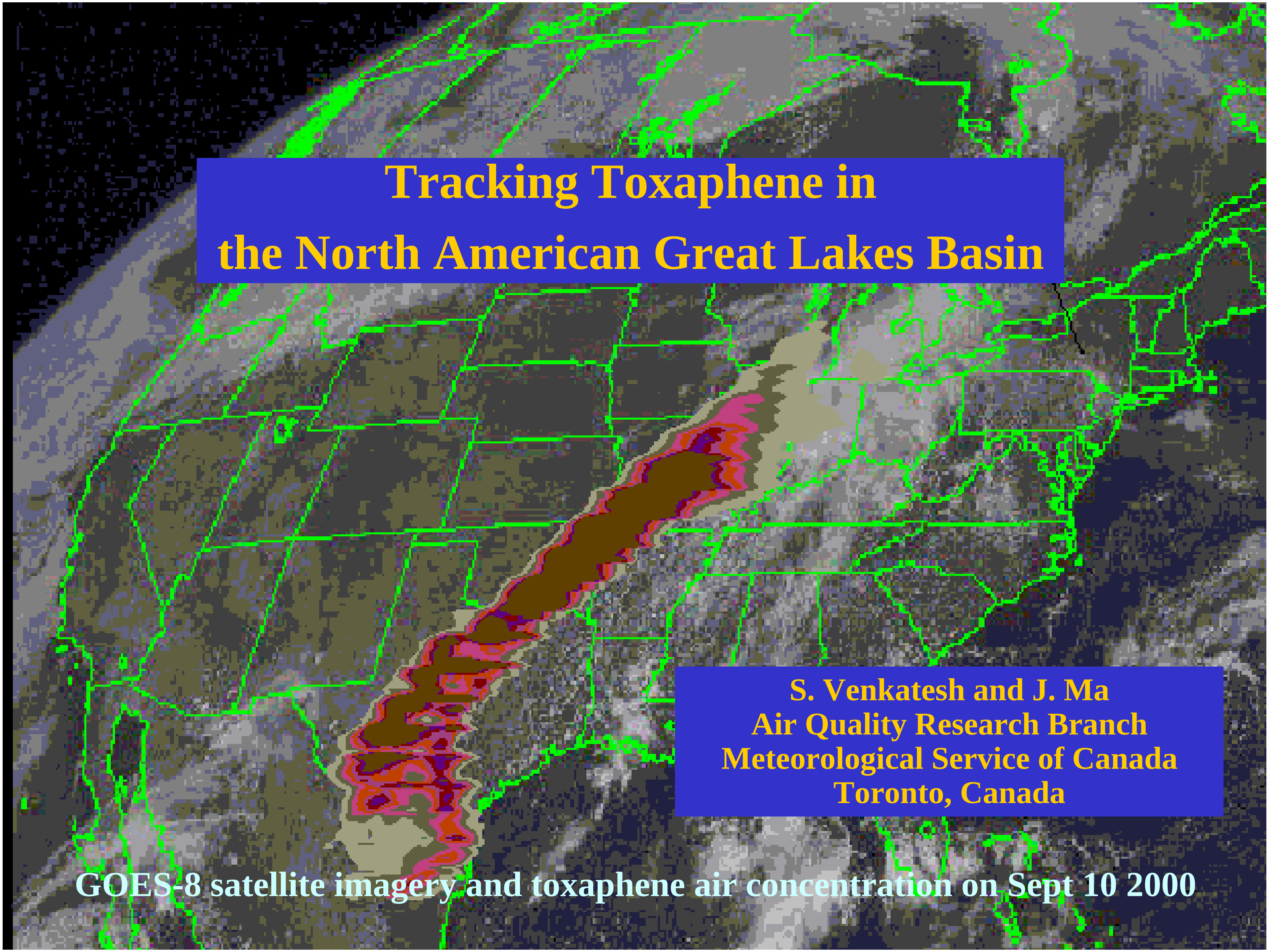

Tracking Toxaphene in the North American Great Lakes Basin

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Air Quality Research Branch
Meteorological Service of Canada
Toronto, Canada

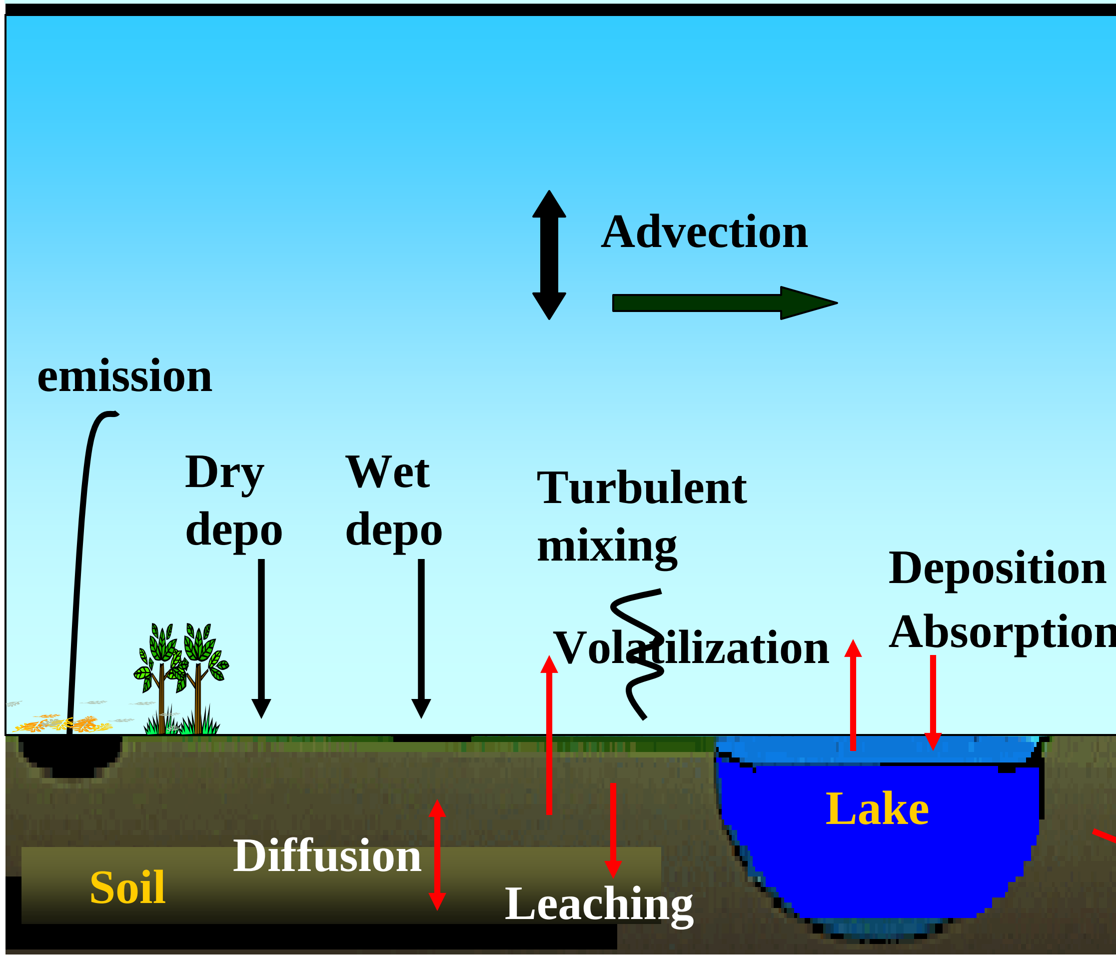
GOES-8 satellite imagery and toxaphene air concentration on Sept 10 2000

Why toxaphene?

- One of the most heavily used organochlorine pesticides, U.S. has been the largest user of toxaphene in the world
- One of “Dirty Dozen” toxics on the list of the Stockholm Convention on persistent organic pollutants
- One of 16 Tier II toxic substances listed by GLWQA
- One of Level I pesticides affecting human heath and environment listed by USEPA
- Still a major contaminant in the Great Lakes fish after the compound was banned in early 1980s in North America
- *Major sources of toxaphene affecting the GL ecosystem are still not well understood*
- Good toxaphene emission inventory in MSC

Half life of Toxaphene in soil	10 yrs
Half life in air	A few days

A schematic illustration of pesticides transport



Resolutions:

Horizontal: 24 km

Vertical:12 layers from surface-7 km

Soil: 3 layers

0-0.1 cm (Exchange)

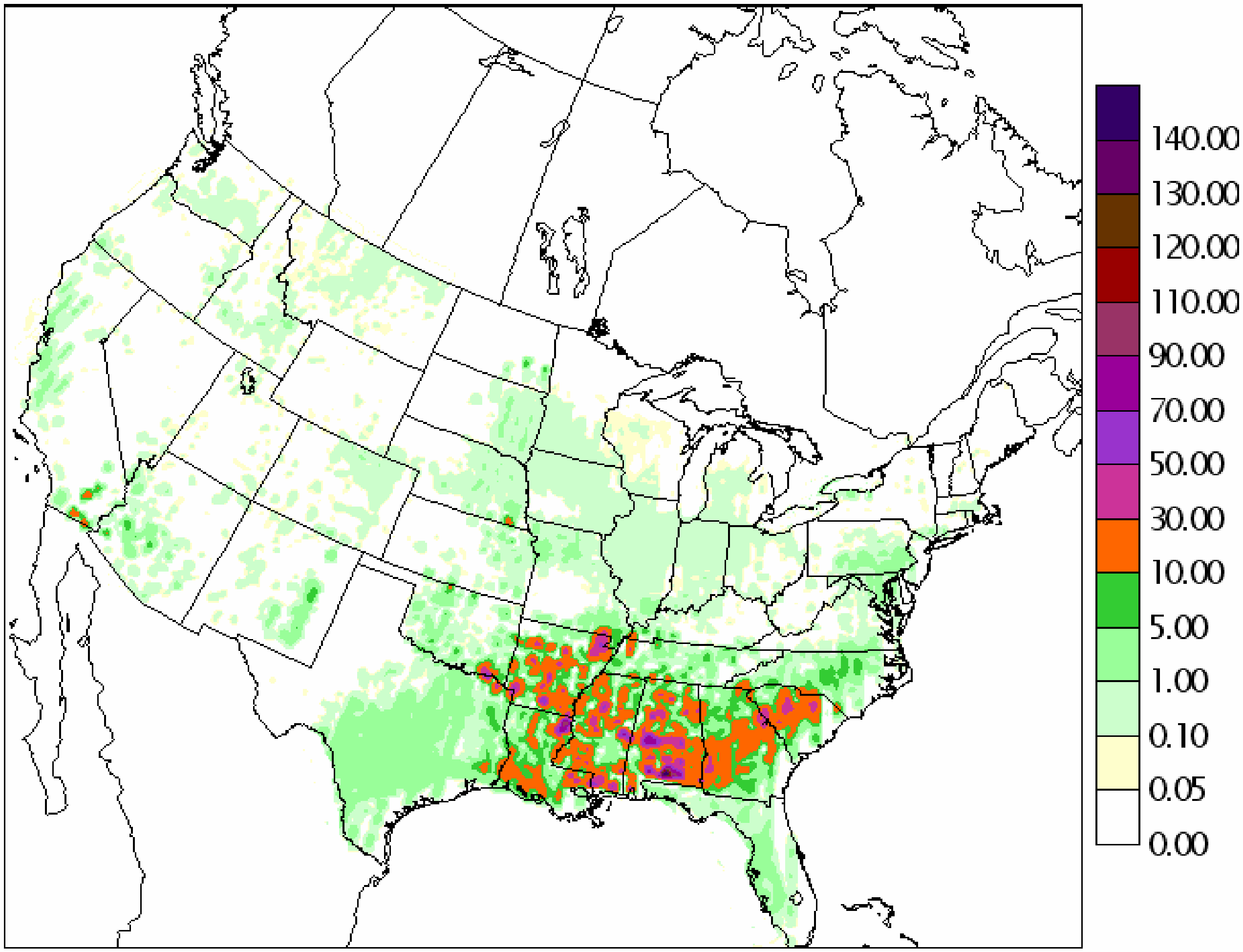
0.1-1.0 cm (Buffer)

1.0-10 cm (Reservoir)

Reaction (e.g., Degradation)

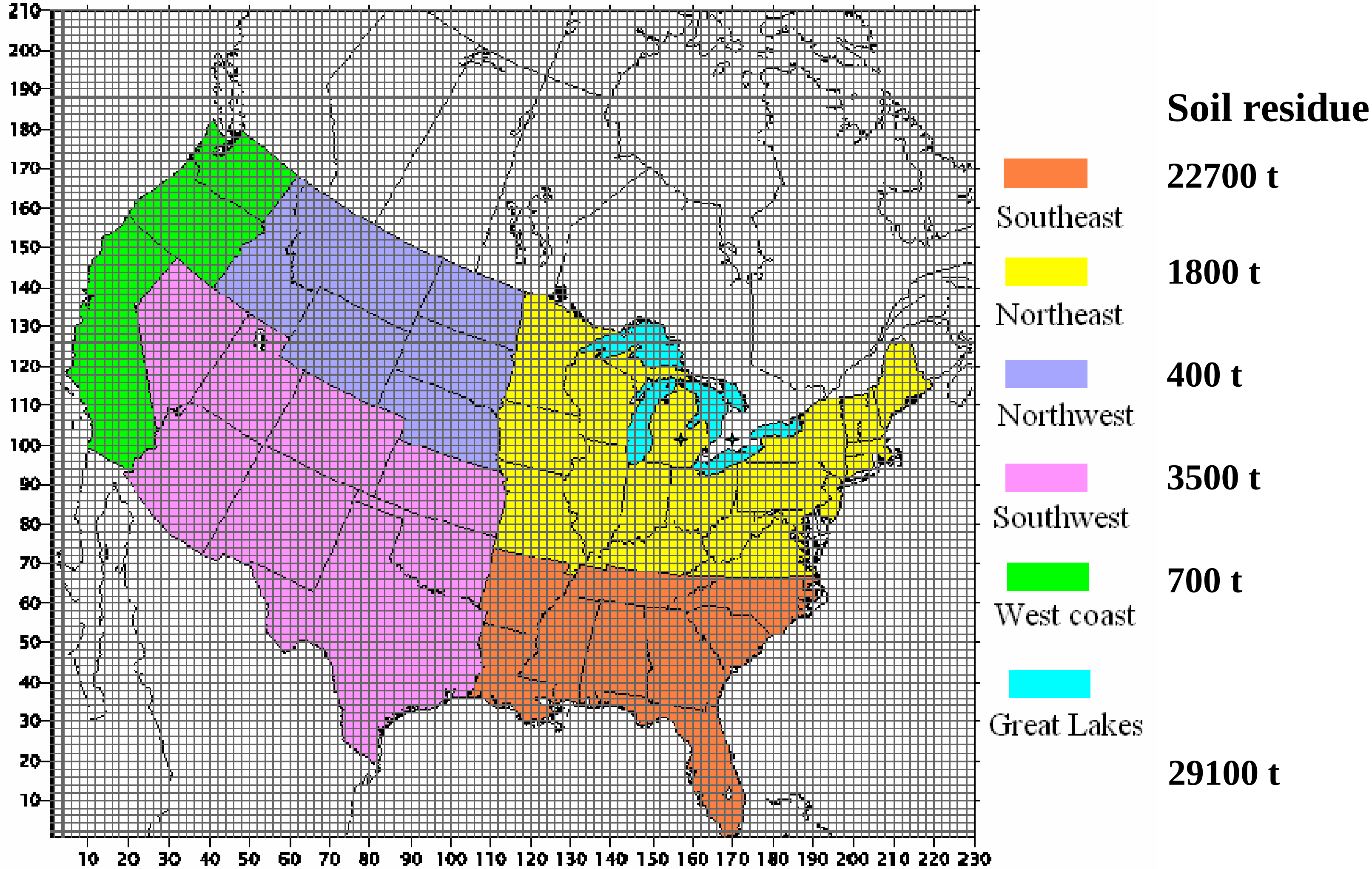
Ma et al, *ES&T*, 2003, 2004; Harner et al, *Environ. Toxicol. Chem*. 2001

Toxaphene Soil residue (ton cell^{-1}), 1 cell = 24 km × 24 km



Maximum: 143 t at grid (142,40) in Alabama

Li et al, JGR, 2001



Model domain, grids, and regions for modeling scenarios

Numerical Experiments setup: *six scenarios*

Scenario 1. With all toxaphene sources in the U.S
Scenario 2. sources in the southeast U.S. only
Scenario 3. sources in the northeast U.S. only
Scenario 4. sources in the northwest U.S. only
Scenario 5. sources in the southwest U.S. only
Scenario 6. sources in the west-Coast U.S. only

- **Model run: from January 1st 2000 to December 31th 2000**

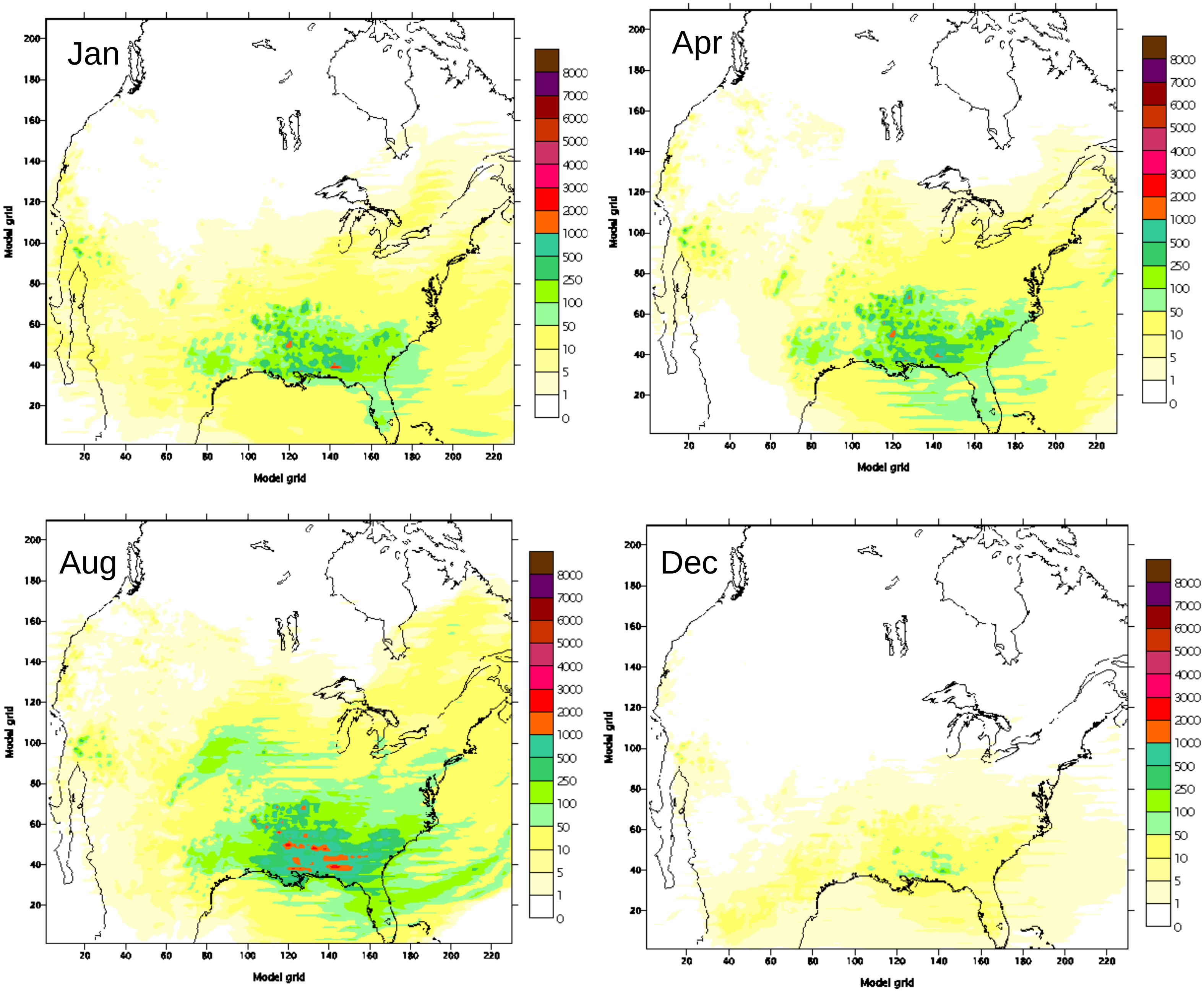
Initial condition:

- **Toxaphene soil residues on 1st Jan. 2000 were assumed to be in the Reservoir Layer, as legacies from past application.**
- **No Initial background air concentration.**

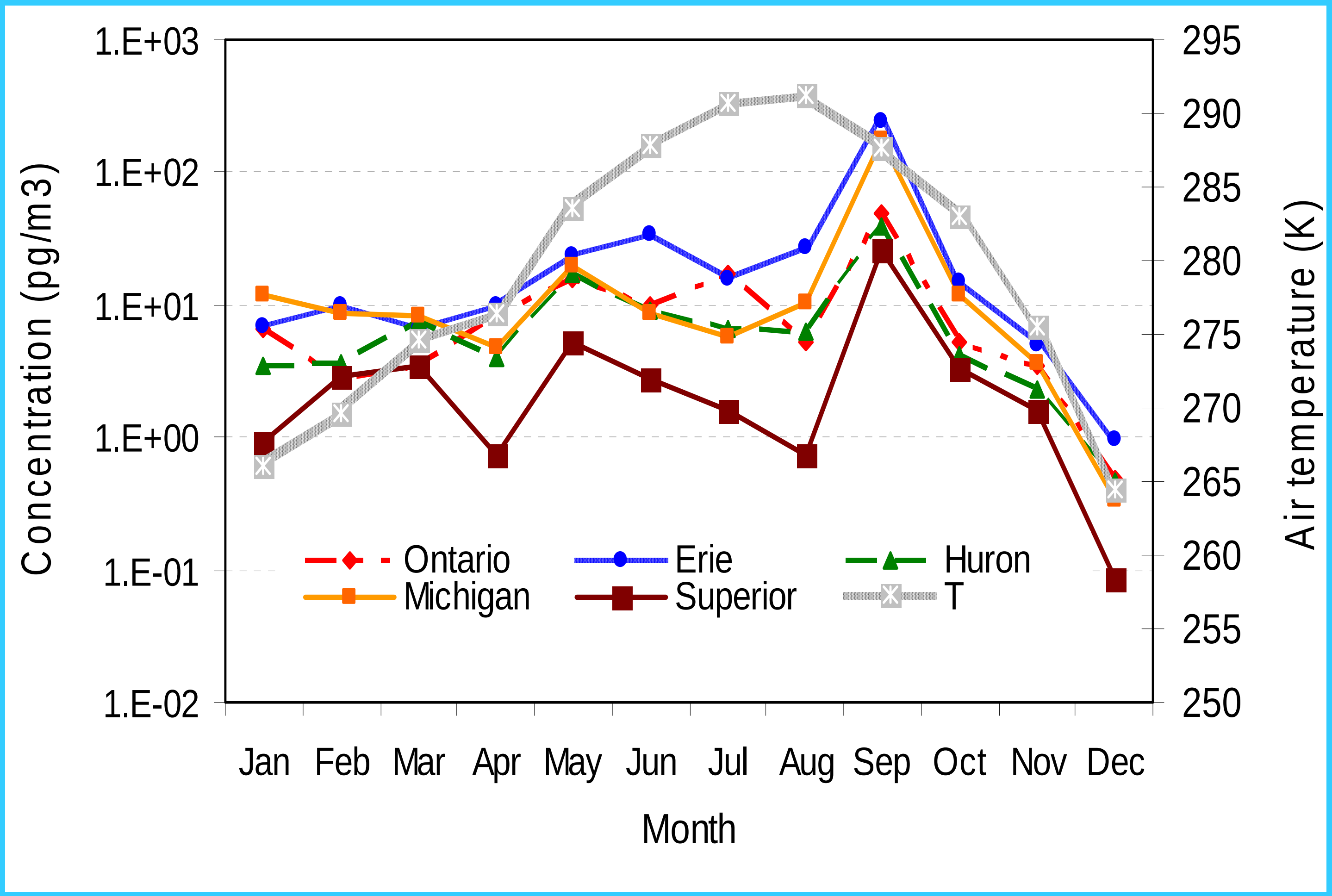
Meteorology: GEM objective analyzed winds and temperature, and predicted precipitation

Toxaphene is treated as a single chemical compound with averaged physical-chemical properties for the mixture

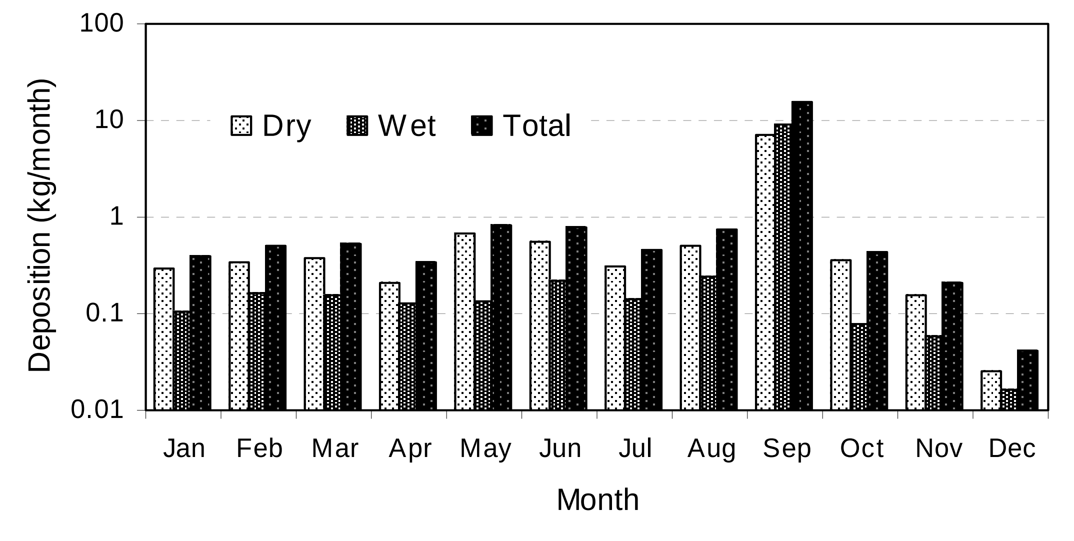
Unit: pg m^{-3}



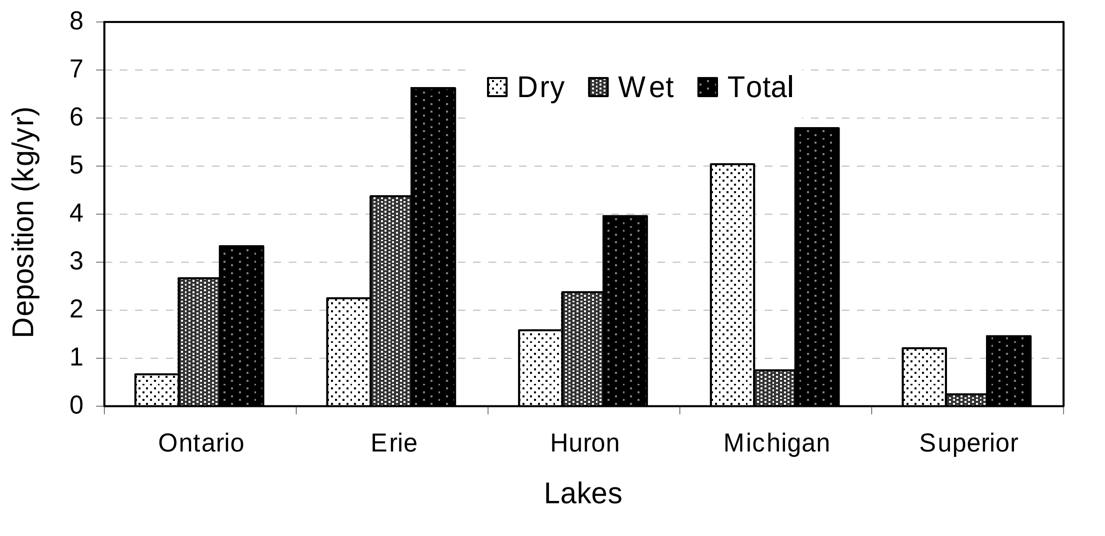
Modeled monthly mean daily air concentration (**All Sources of toxaphene**)



Toxaphene - Monthly averaged daily air concentration over each lake (pg m^{-3}) in 2000



Monthly dry, wet and total depositions (kg month^{-1}) to all five lakes



Modeled annual dry, wet and total (dry + wet) depositions (kg yr^{-1}) to each lake in 2000

Annual total deposition

Superior

Model: 1.5 kg in 2000

Measured: 19 kg (mid-1990s)

Michigan

Model: 5.8 kg in 2000

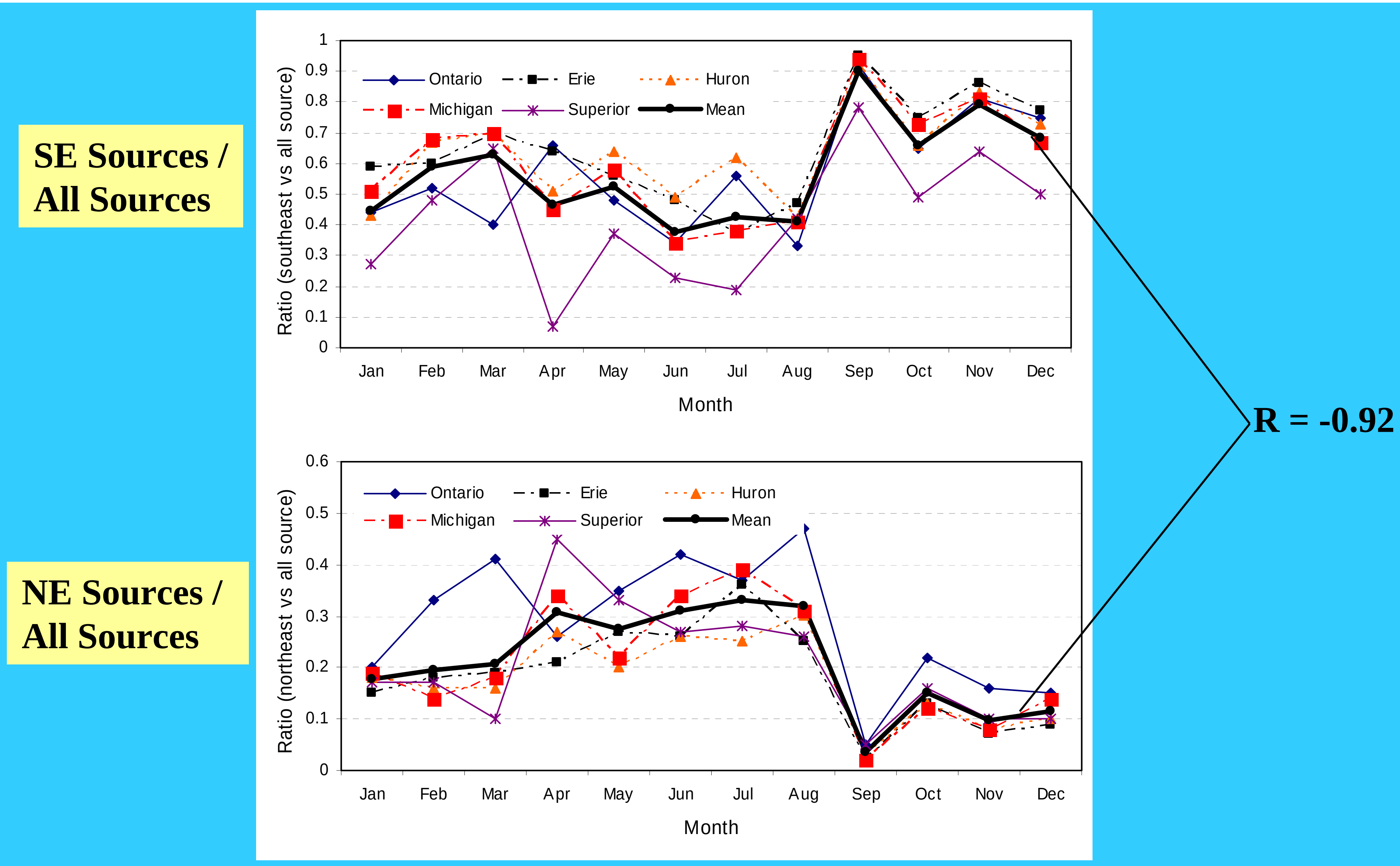
Measured: 13.6 kg (mid-1990s)

Ontario

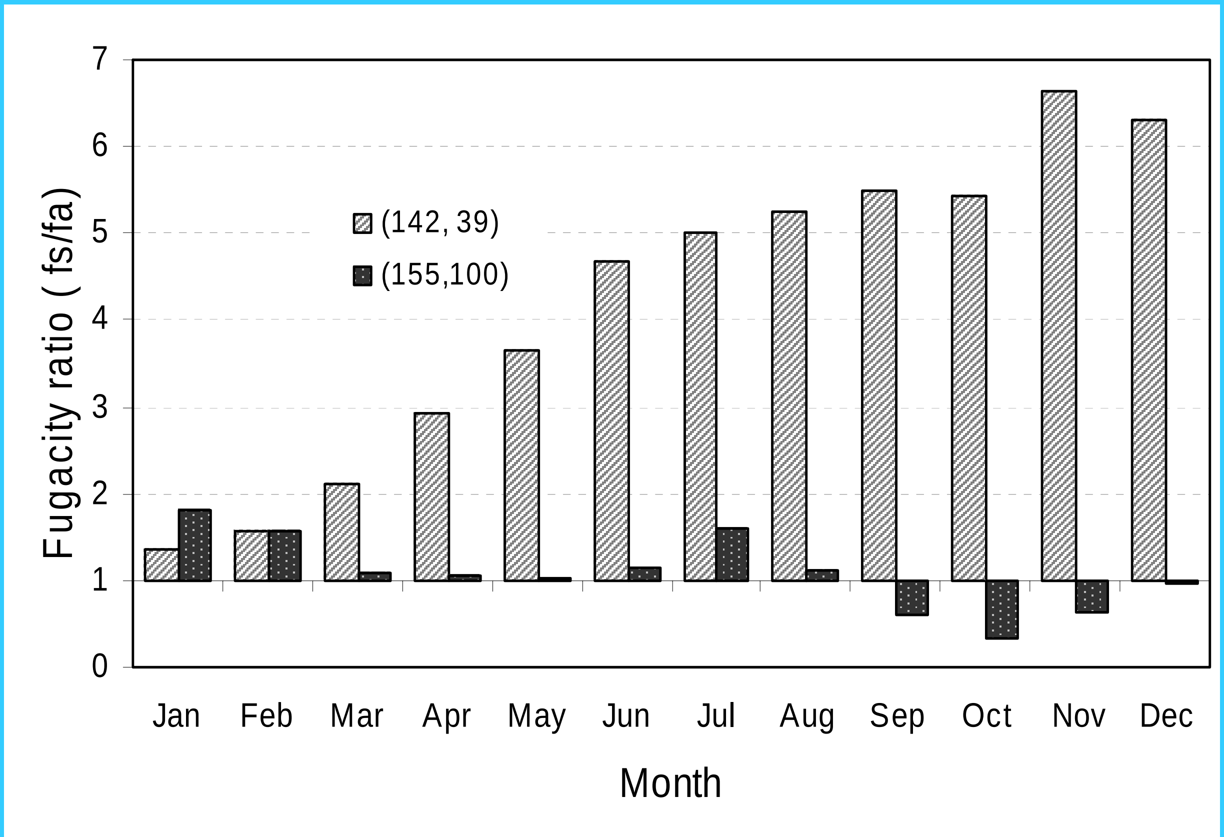
Model: 3.3 kg in 2000

Measure: 5 kg (mid-1990s)

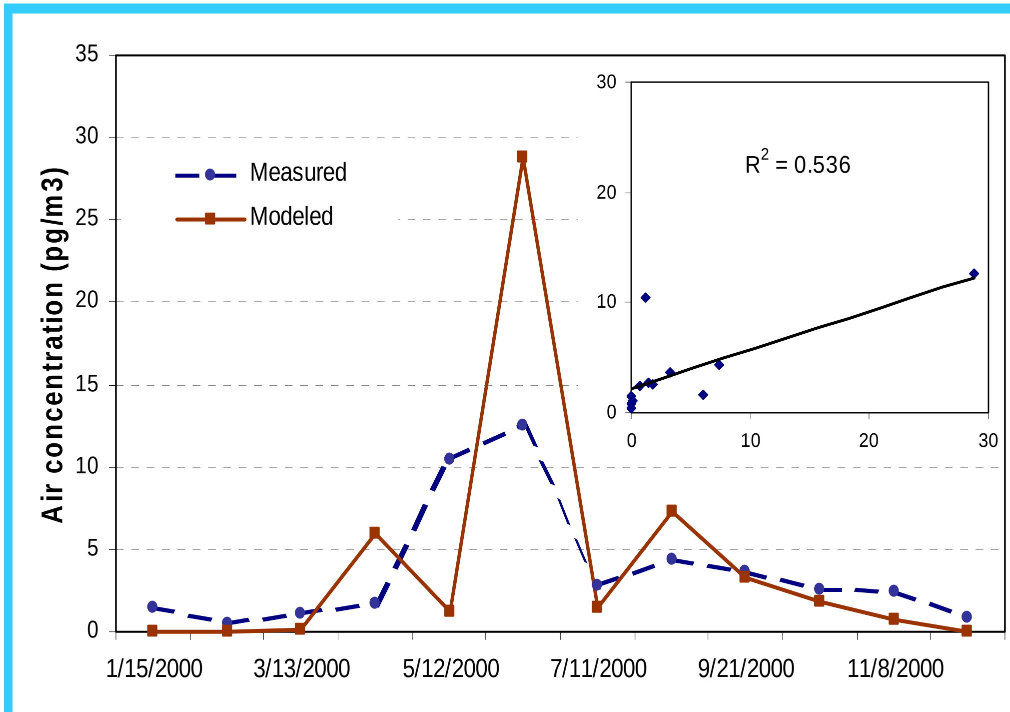
Measured by Swackhamer et al *ES&T*, 1999.



Monthly contribution of southeast (major) and northeast U.S. (Near the Great Lakes) toxaphene sources to the toxaphene budget over the Great Lakes: Southeast sources (strong emissions) made a larger contribution in spring and fall than in summer, whereas the contribution from northeast sources (weak emission) is maximum in the summer. The negative correlation is associated with atmospheric circulation patterns



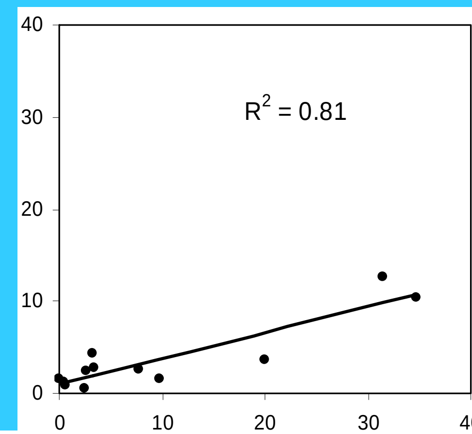
Model calculated toxaphene soil/air fugacity ratio (fs/fa) at model source grids (142, 39) in Alabama with soil residue at 135 t cell^{-1}, and (155, 100) in southern Michigan with soil residue at 0.12 t cell^{-1}. Soil fugacity was taken at reservoir layer (1-10 cm below the surface) and air fugacity was taken at 1.5 m height.

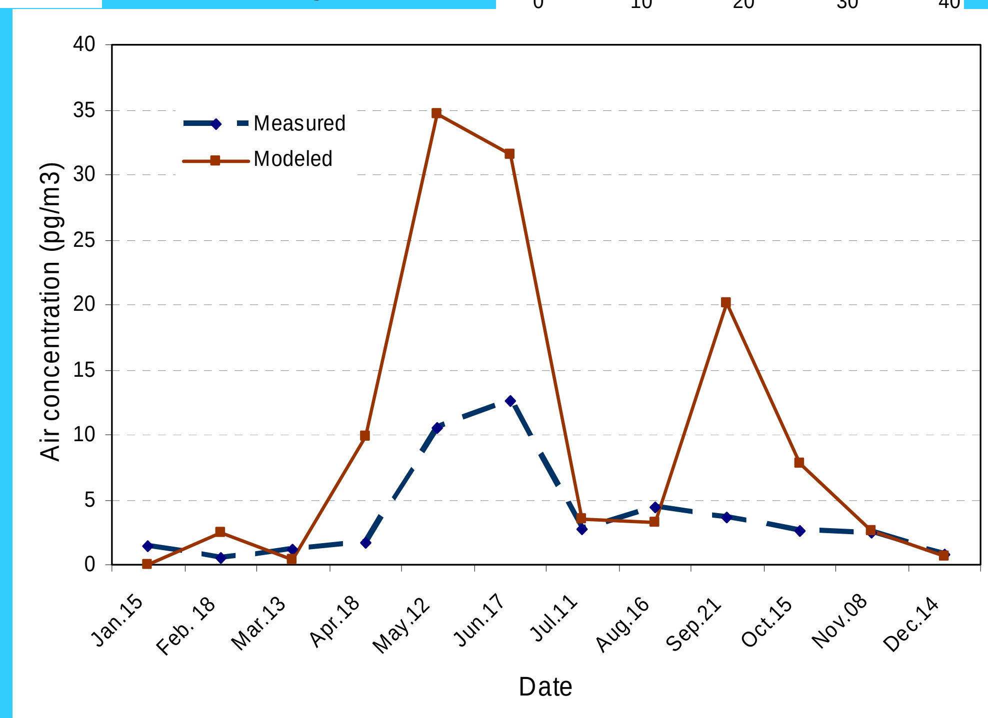


Unit: pg m^{-3}

Daily

3 days





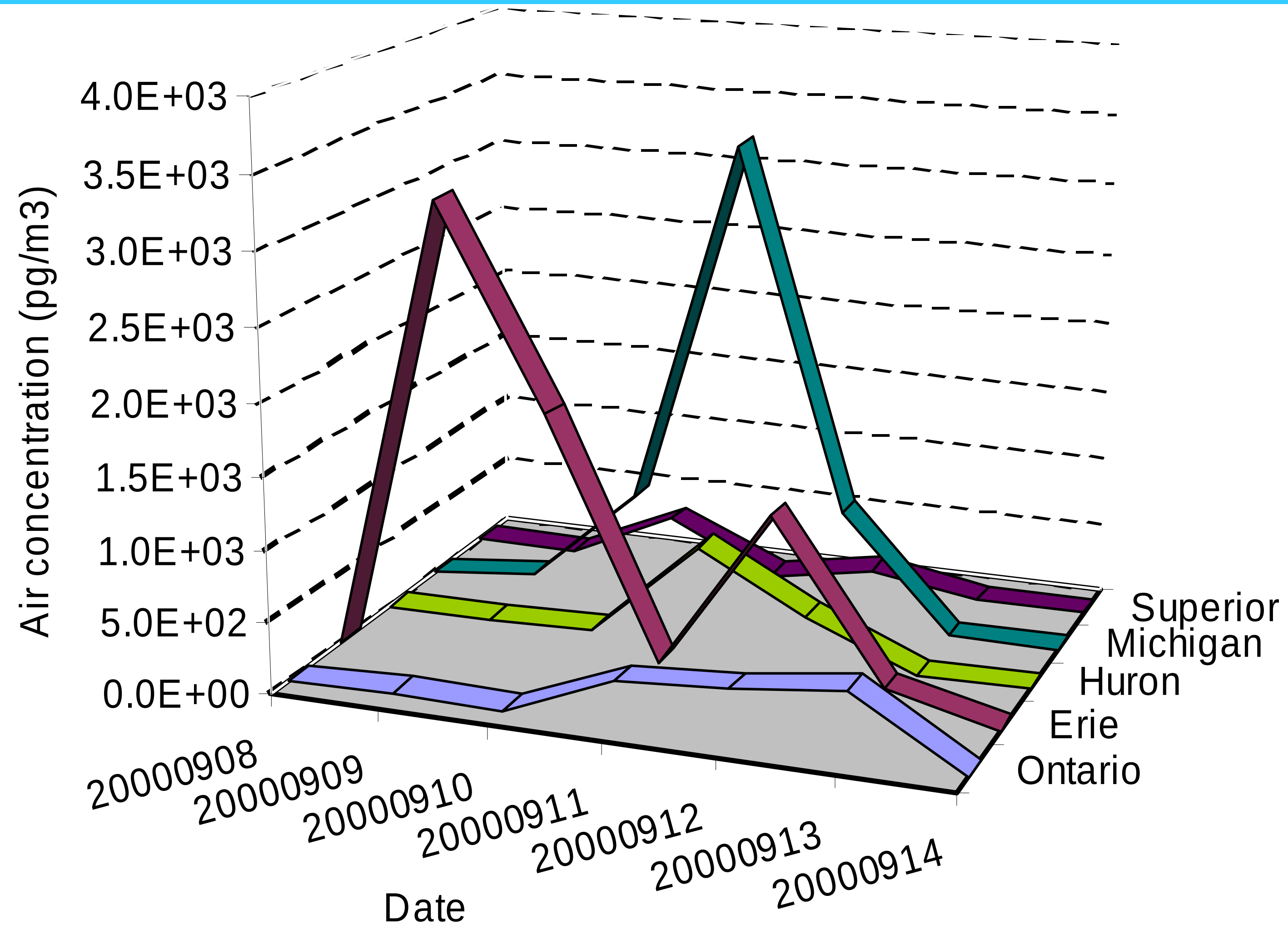
Comparison between modeled and measured air concentration at Point Petre (Lake Ontario)

Mean concentration (pg m^{-3}) in June 2000:

Lake Ontario (ship): 25±20

Model: 15 (averaged over Lake Ontario)

Point Petre: ~10

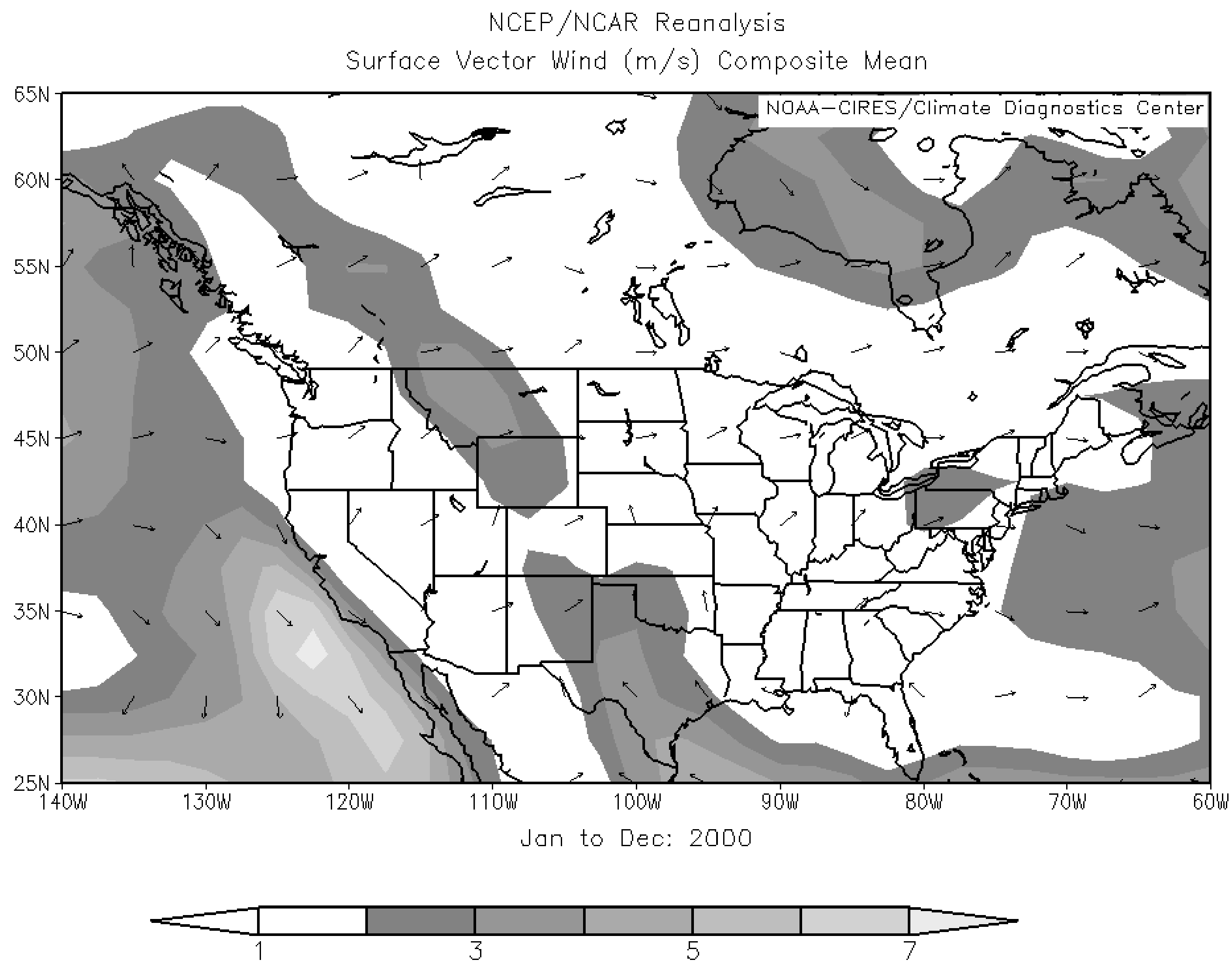


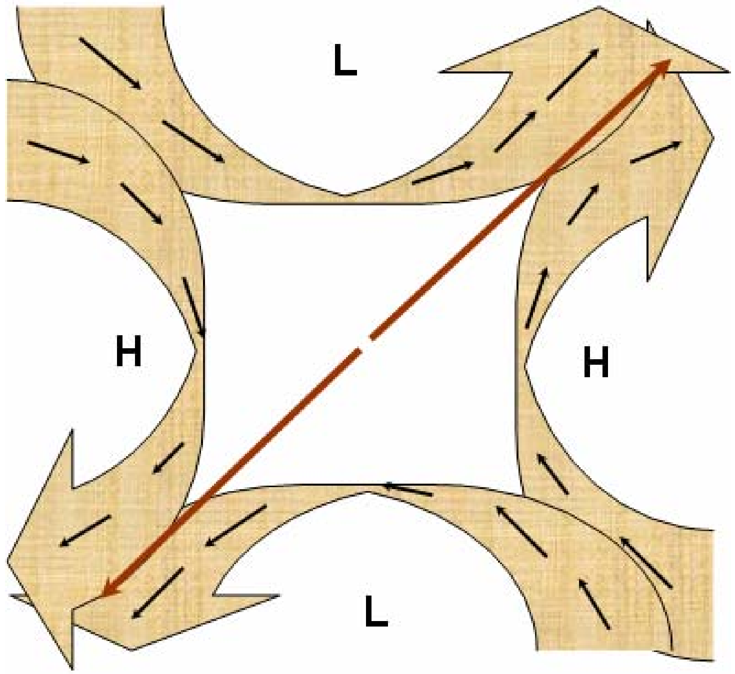
The September Event

Episodic long-range/trans-boundary transport

September event

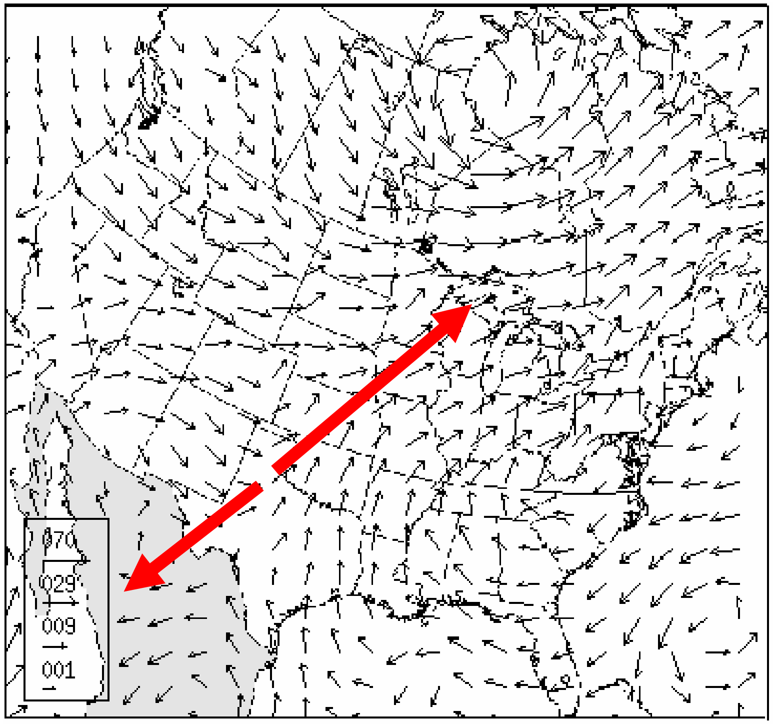
- Nature of source of pollutants
- Atmospheric flows with minimal dispersion
- Limited chemical destruction (no chemical or photochemical degradation, long-enough half-life in air)


NCEP/NCAR Reanalysis
Surface Vector Wind (m/s) Composite Mean
NOAA–CIRES/Climate Diagnostics Center
65N
60N
55N
50N
45N
40N
35N
30N
25N
140W
130W
120W
110W
100W
90W
80W
70W
60W
Jan to Dec: 2000
1
3
5
7

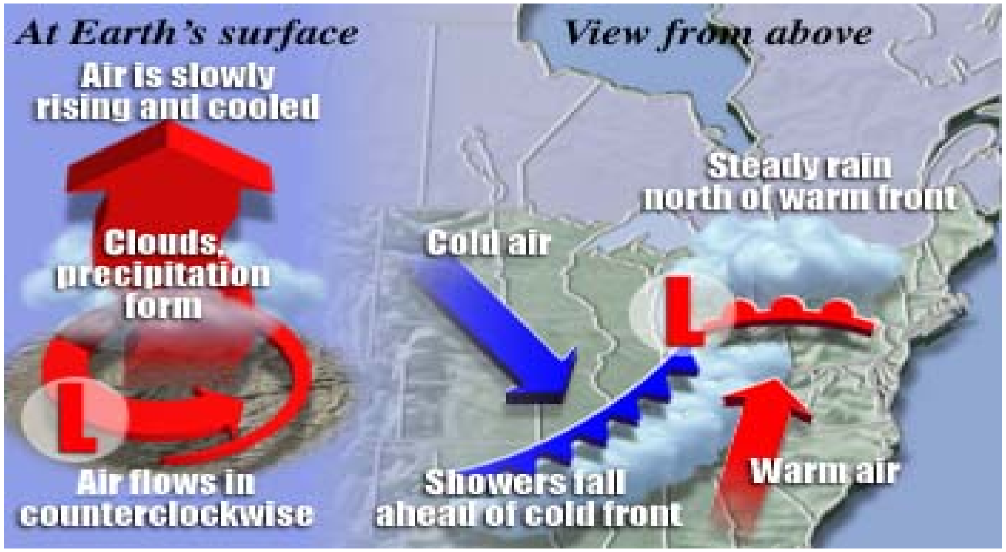


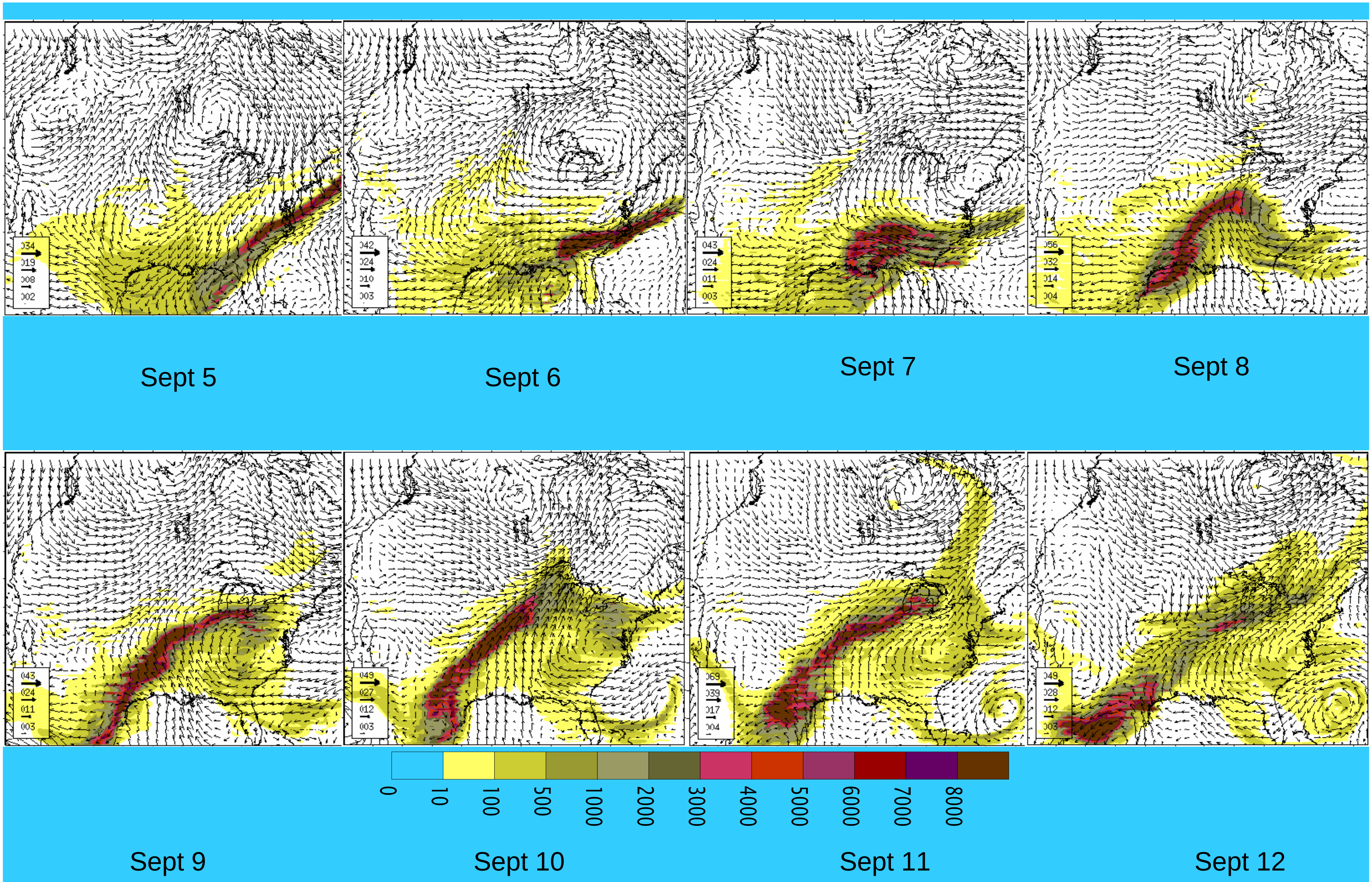
A schematic view of a shearing **deformation** wind field consists basically of an area of flat pressure between two opposing highs and two opposing lows. The **axis** of deformation flow is an area where **strong convergence** occurs.

Flow deformation acts to increase the horizontal temperature gradient and convergence, leading to a frontogenesis (**initial formation of a front through an increase in the horizontal gradient of temperature**)



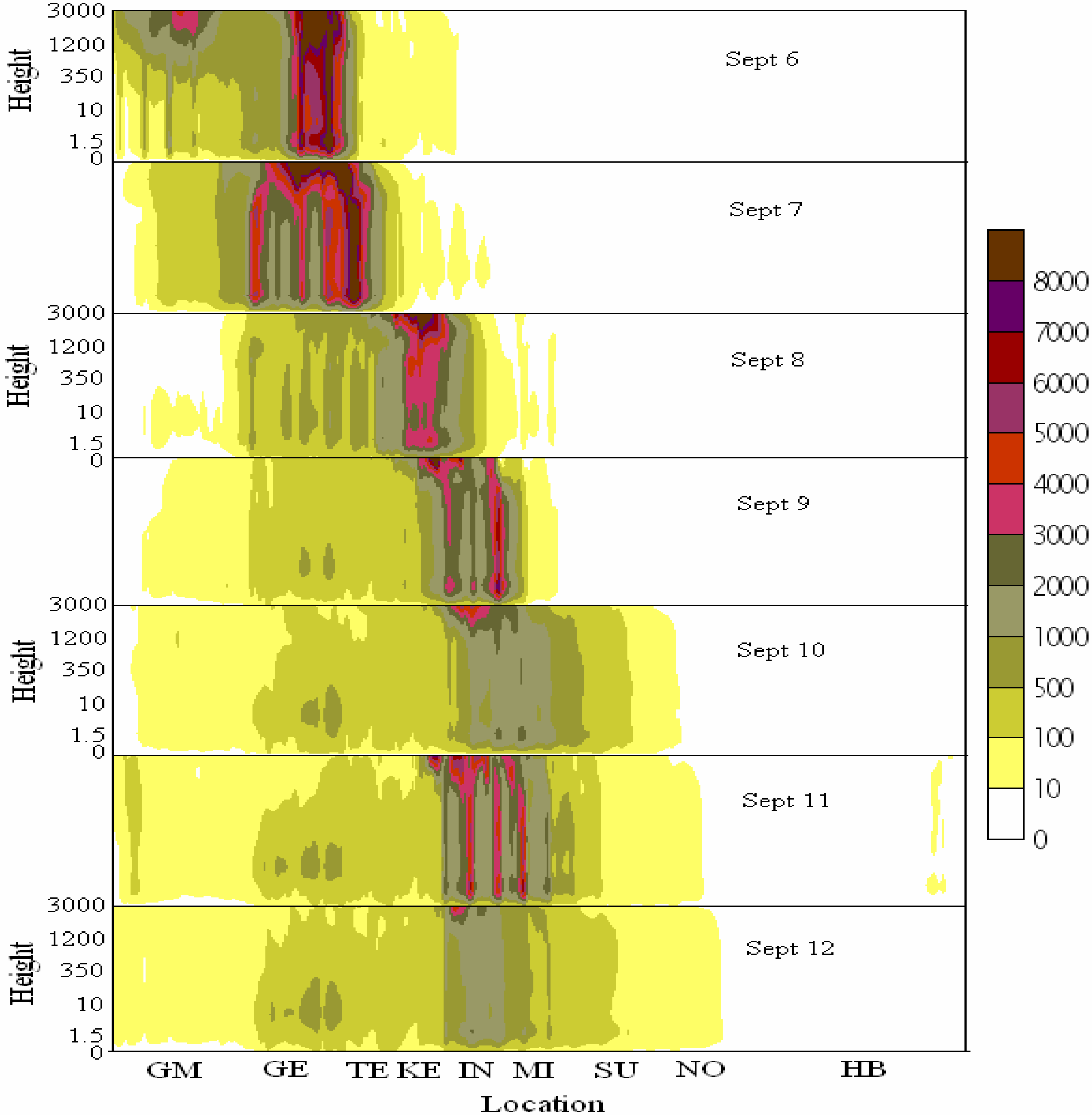
Vector winds at 1200 m height on Sept 11 2000

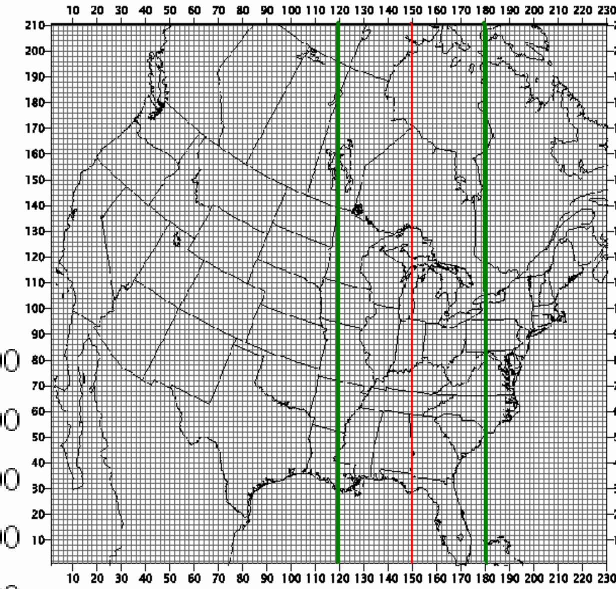




Modeled daily air concentration during September event; vector winds (m s^{-1}) at 1200m

Unit: pg m^{-3}





GM-Gulf of Mexico

GE-Georgia/Alabama

TE-Tennessee

KE-Kentucky

IN-Indiana

MI-Michigan

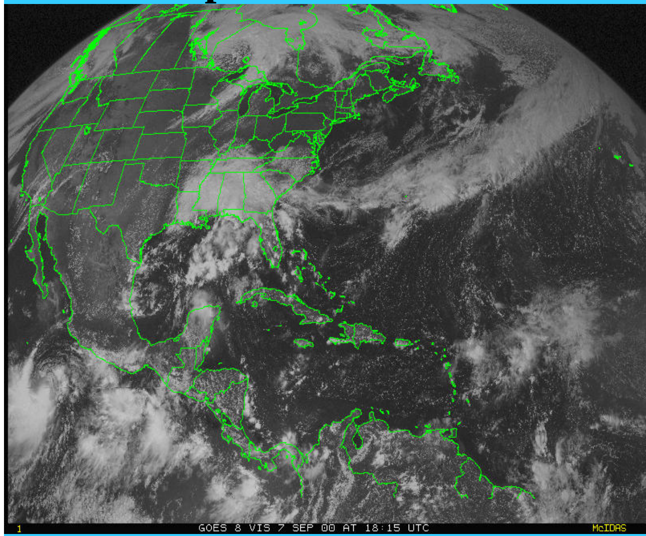
SU-Lake Superior

NO-Northern Ontario

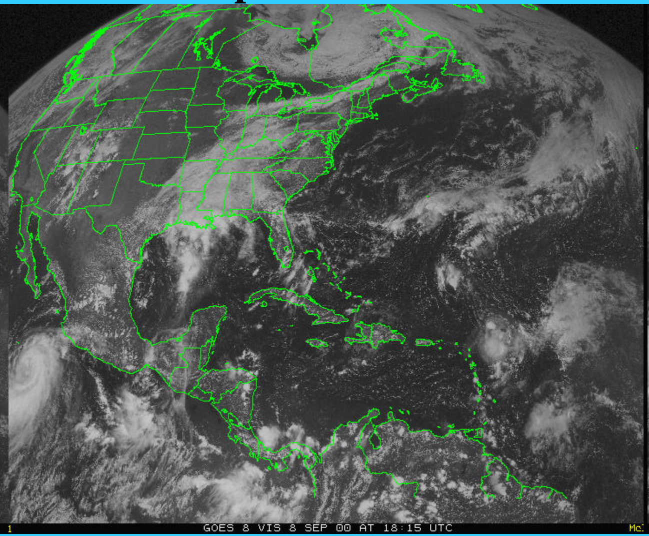
HB-Hudson Bay

Cross-section/vertical profile of air concentration indicating northward transport of toxaphene

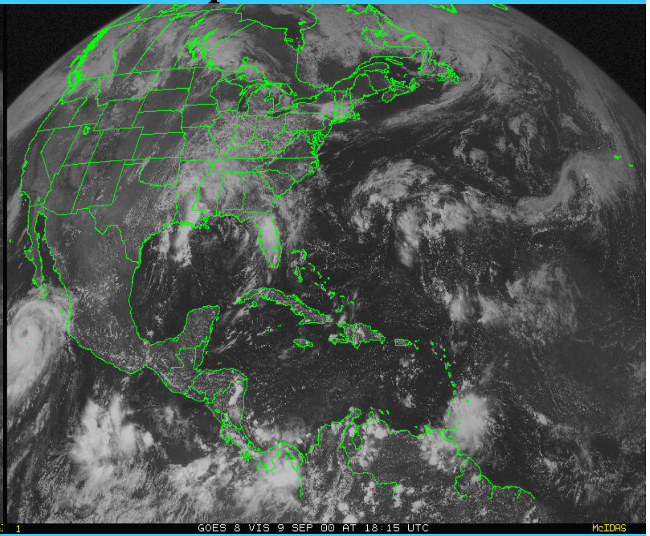
Sept 7



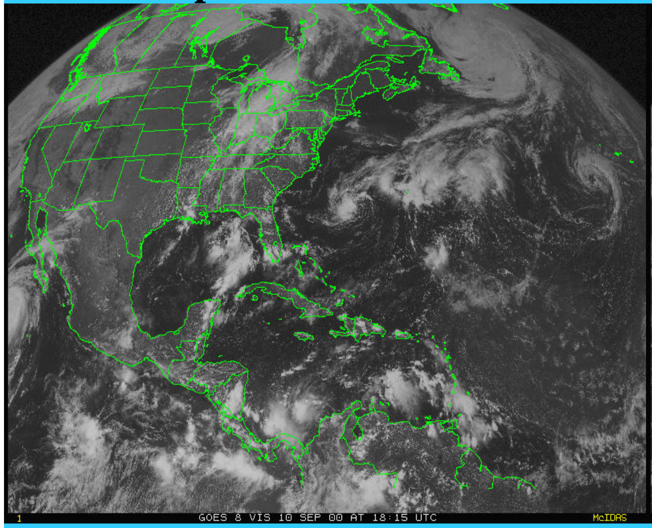
Sept 8



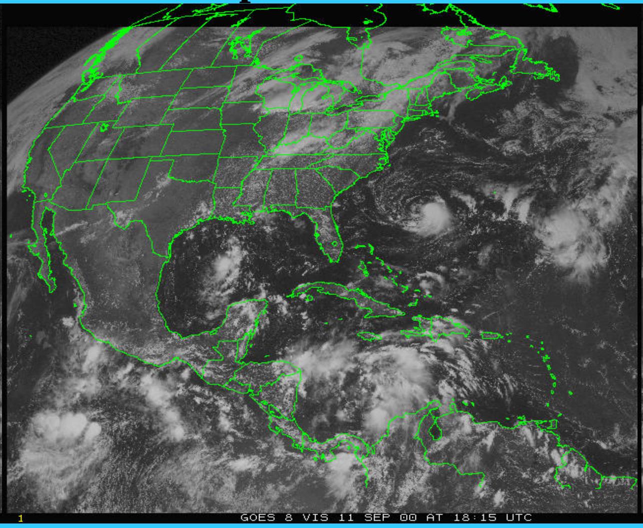
Sept 9



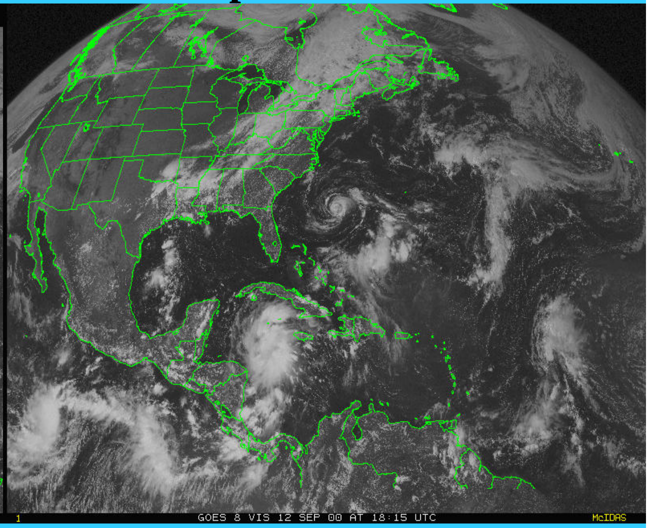
Sept 10



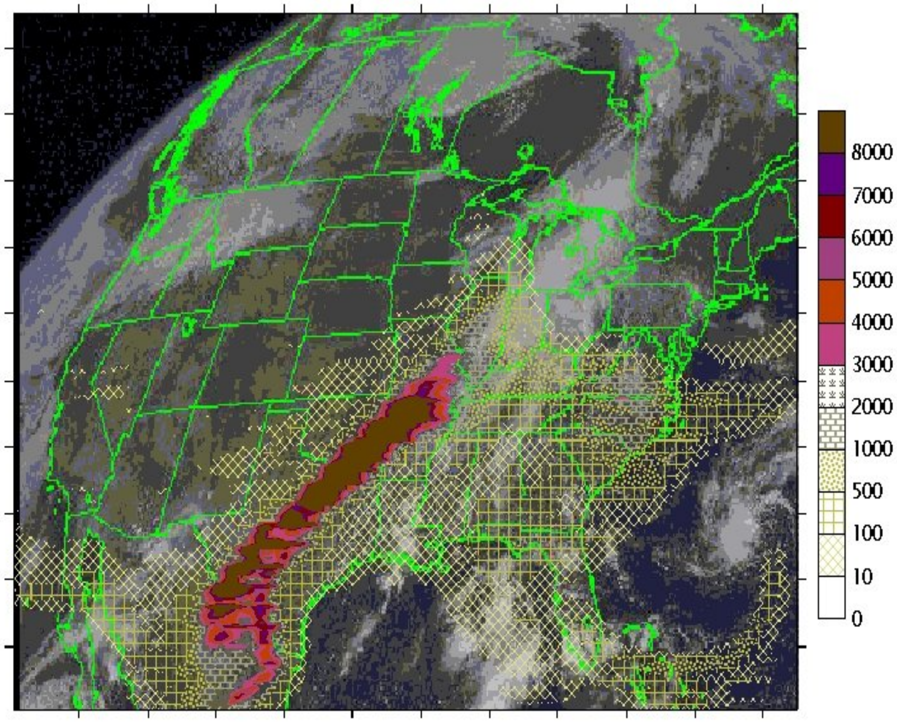
Sept 11

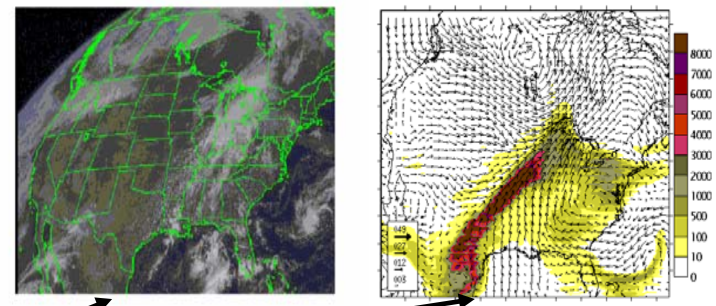


Sept 12



NOAA Geostationary Satellite (GOES-8) visible image

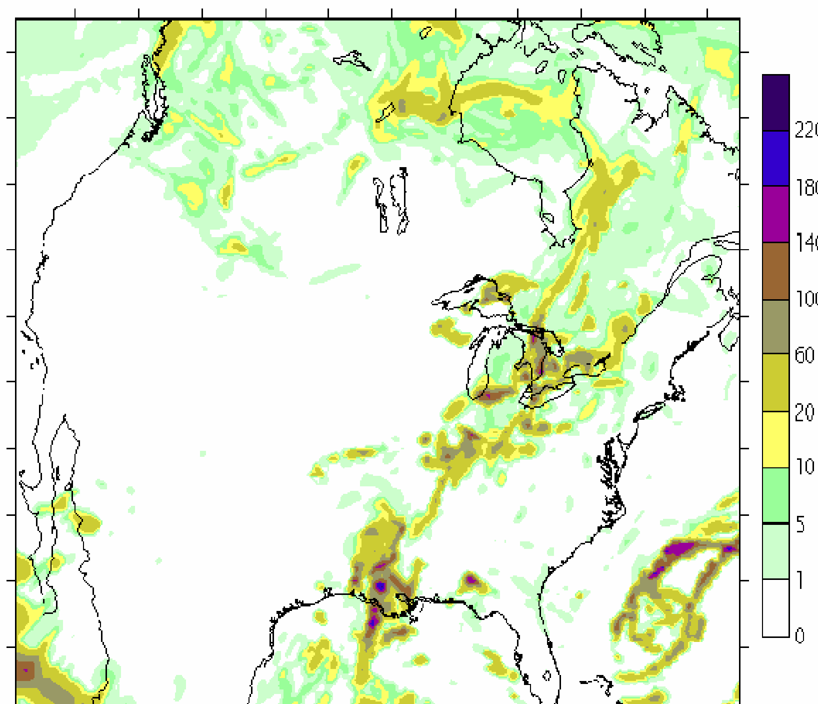


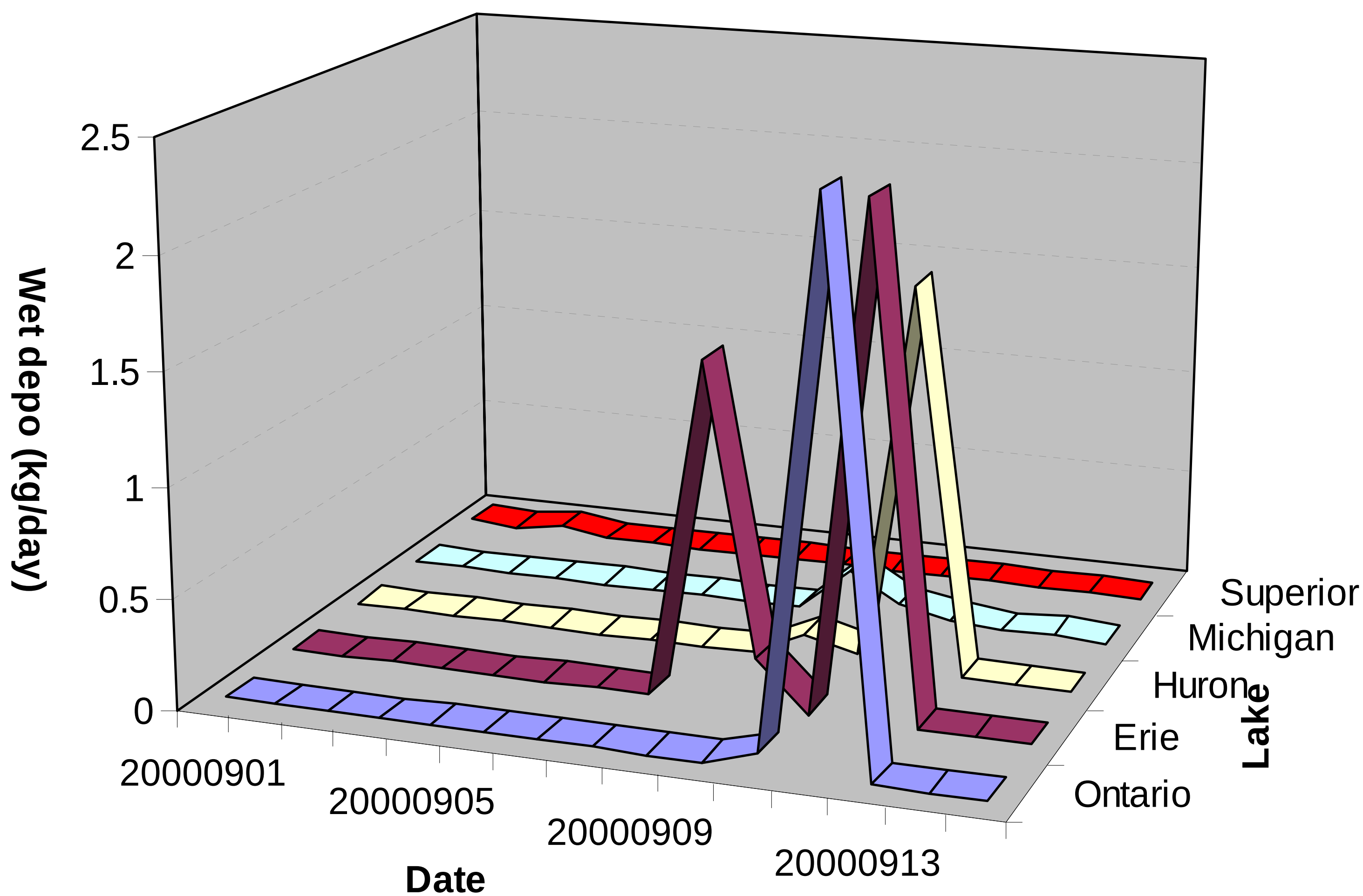


GOES-8 visible satellite imagery on 10 September at 18:15 UTC and daily toxaphene air concentration at 1200 m on 10 September 2000

Warm and humid air was also transported from southern U.S. / Gulf of Mexico to the Great Lakes, resulting in heavy rain and wet deposition to the lakes.

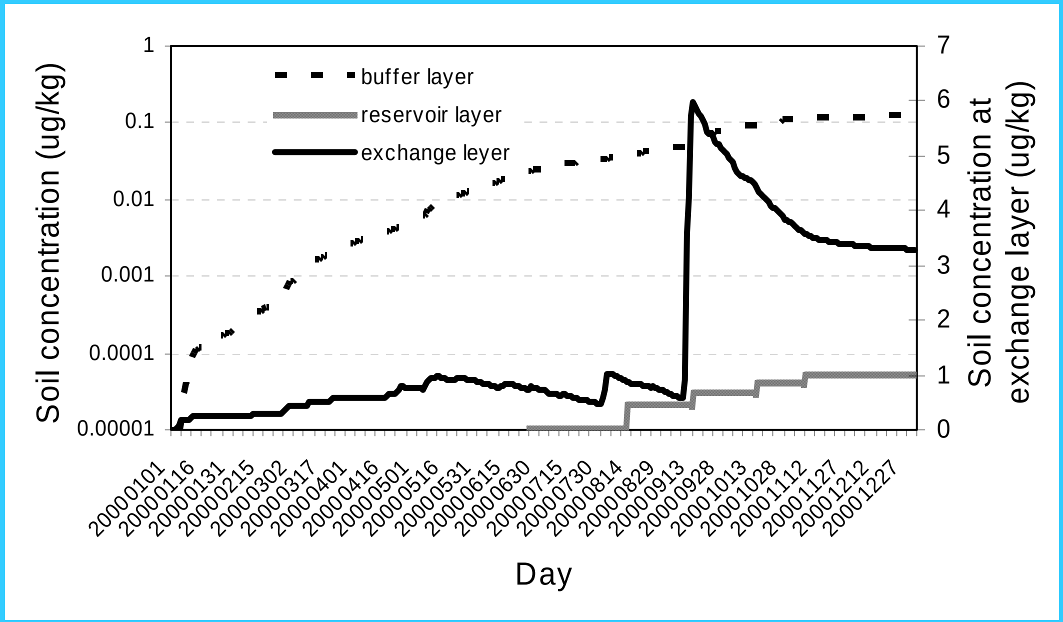
GEM predicted total precipitation (mm) accumulated over 9-12 September

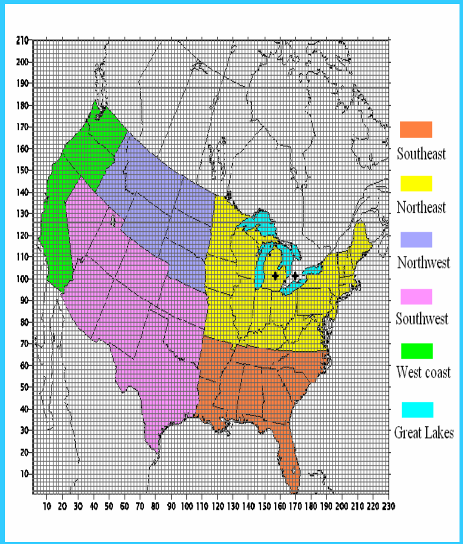




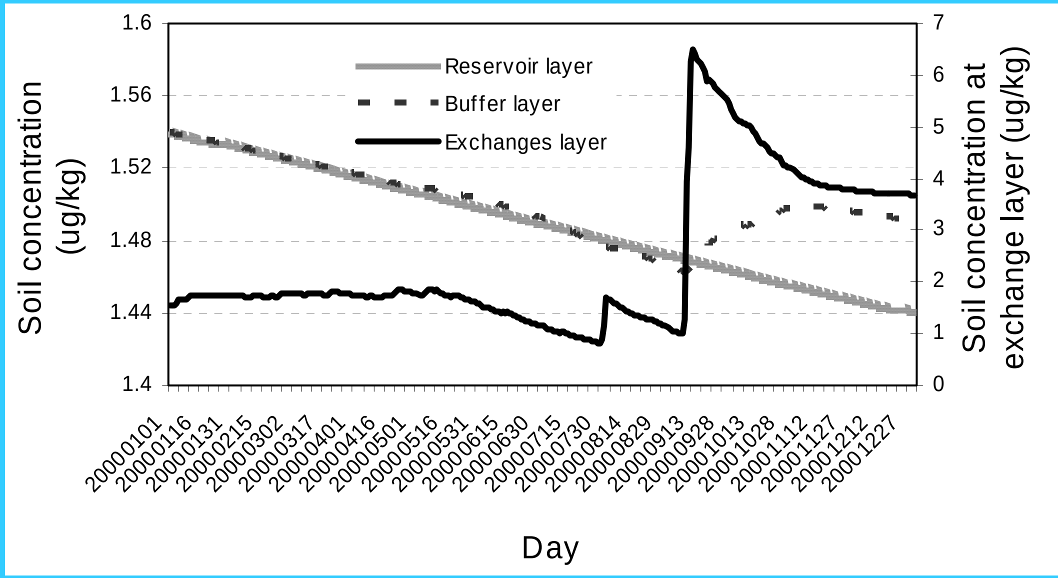
Wet deposition to the lakes (kg day^{-1})

Grid point in Ontario - a Receptor

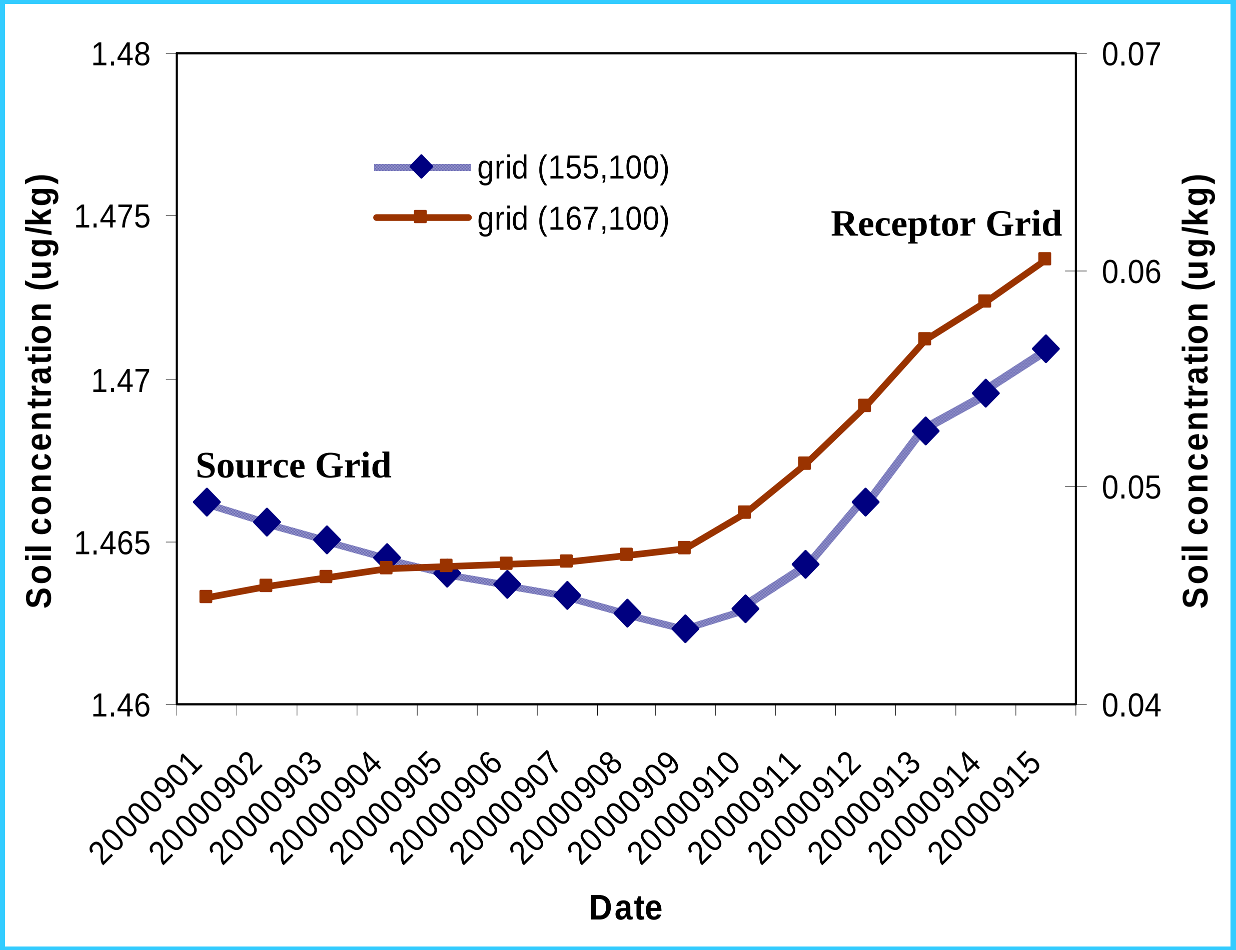




Grid point in Michigan – a Source



September event: A memory in soil



Soil concentration ($\mu g\ kg^{-1}$) in buffer layer (0.1-1 cm below ground surface)

Summary

1. The southeast U.S. is a dominant source contributing to toxaphene levels in the atmosphere over the Great Lakes basin and depositions to the lake waters.

2. In spring and autumn, relative contributions of SE sources to GL basin are higher than those of NE sources, but of similar magnitudes in summer
   - primarily due to the inter-seasonal changes in atmospheric circulation systems

3. Episodic long-range transport is a major pathway for moving toxaphene from its sources in the southern U.S. to the Great Lakes
   - During the *September event*, *d*eformation flow and convergent winds formed a conveyer belt for toxaphene transport from the southeast U.S. to the Great Lakes.

Acknowledgements

This study supported by

- Environment Canada
- Great Lakes Binational Toxics Strategy

LRT of Organochlorine pesticides
Info Table July 2005

	Lindane	Endosulfan	Toxaphene	HCB	BaP	Atrazine	DDT
Strategy substance (Level I or II)	II		I	I	I		I
LRT potential	H[1, 2]	M[2]	H[1]	H[1, 2]	H	L	H[1,2]
NA Emis Inv (Grid ^{0}Lon x ^{0}Lat)	1/4°x1/6°	1/4°x1/6°	1/4°x1/6°	Under development	Under development	1/4°x1/6°	
Global Emis Inv (Grid ^{0}Lon x ^{0}Lat)	1°x1° (incomplete)	1°x1° (incomplete)					1°x1°
Estimated Current emissions – NA (tonnes)	370 (usage in 2001)[3]	850 (usage in 2002)[3]	740 (2005)[3]	1.6[11]		35500 (usage in 2002)[3]	470 (2004)[3]
Estimated Current emissions – Global (tonnes)	1300 (usage in 2001)[3]	11,000 (usage in 2002)[3]		10-100[12]			3000 (2002)[3]
Half life in air (days)	4-90 [4]	3[7]	5-7[9]	700[6]	3.5-10[6]	0.6[15]	5-7[16, 17]
Half life in soil (months)	24 [5]	1.7[7]	70-120[6]	36-72[6, 13]	0.1-23[6]	2-10[15]	24-120[16, 17]
logK_{oa} at 25^{o}C	7.92[6]	6.0[8]	9.3[10]	6.78[6]	10.77[6]	9.68[6]	9.21[8]
logK_{ow} at 25^{o}C	3.7[6]	3.62[8]	5.5[10]	5.5[6]	6.04[6]	2.75[6]	6.19[8]
Henry's Law const** at 25^{o}C (Pa m^{-3} mol^{-1})	131[8]	10.23[8]	0.29[10]	17.6[14]	0.012[14]	0.0003[15]	2.36[8]

** Higher the Henry's law constant, greater the propensity for the chemical to move from Water/soil to air