Yale-NUIST Center on Atmospheric Environment

Aircraft study of the impact of lake-breeze circulations on trace gases and particles during BAQS-Met 2007

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Outline

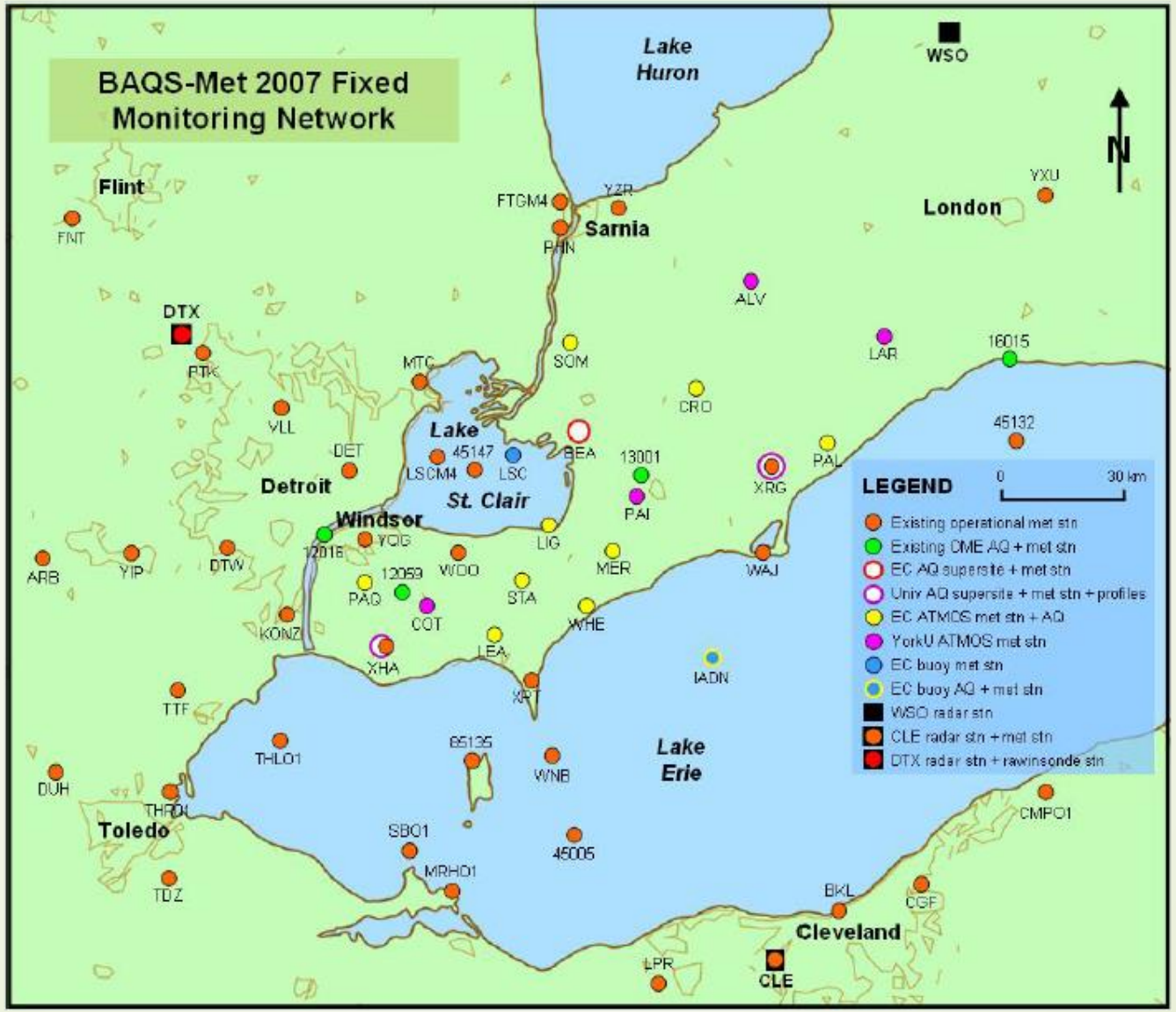
- Introduction
- Background
- Experimental design
- Results and discussion
- Conclusions

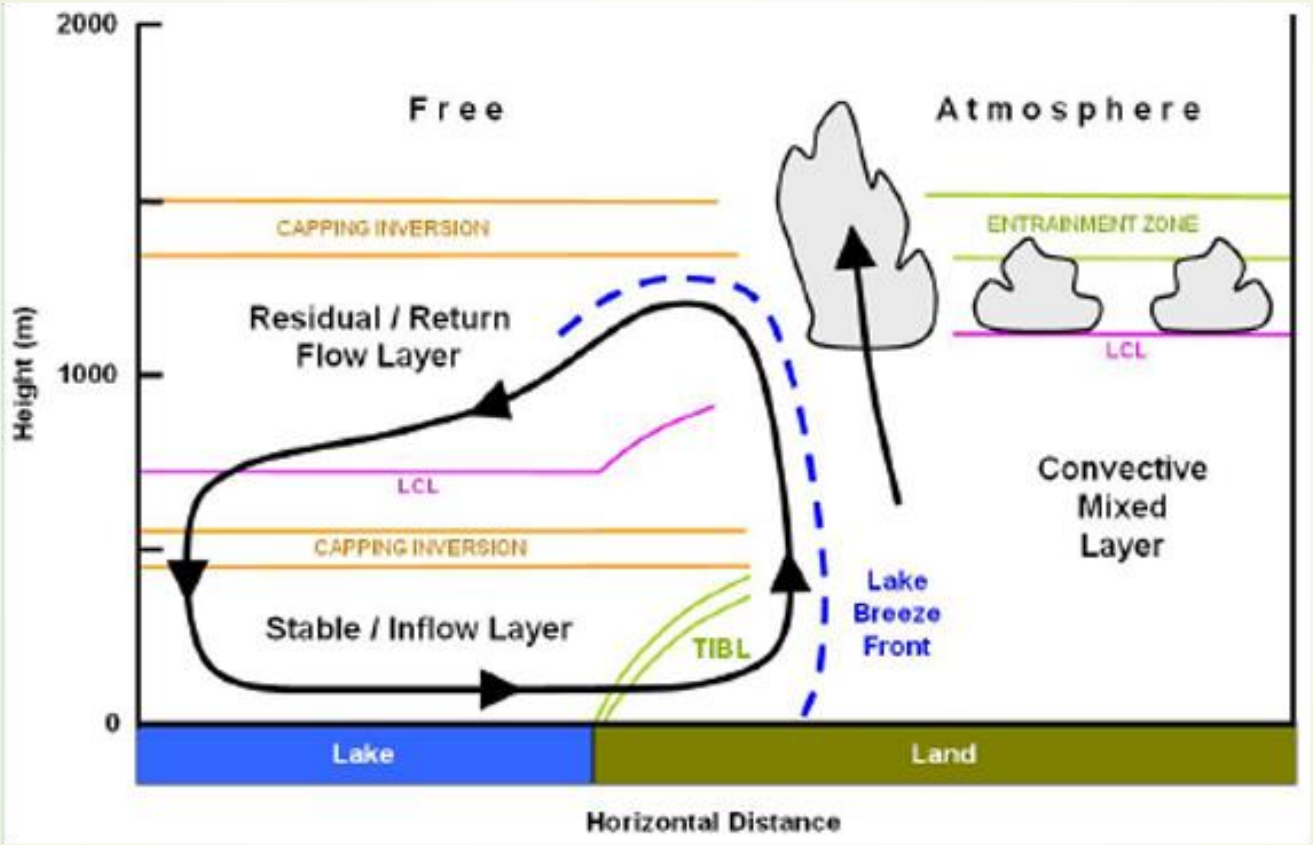
Introduction

- High time-resolved aircraft data, concurrent surface measurements and air quality model simulations were explored to diagnose the processes influencing aerosol chemistry under the influence of lake-breeze circulations in a polluted region of southwestern Ontario, Canada.
- The analysis was based upon horizontal aircraft transects conducted at multiple altitudes across an entire lake-breeze circulation.

Background

- The Border Air Quality and Meteorological Study (BAQS-Met) is a major collaborative effort between university, federal and provincial government scientists to further understand the impacts of trans boundary flow of pollutants, lake effects and gas/particle processes on the high levels of air pollutants that frequently and episodically occur in south western Ontario, particularly in the Windsor-Essex-Chatham-Kent (WECK) region.


BAQS-Met 2007 Fixed Monitoring Network
Lake Huron
WSO
N
Flint
FNT
FTGM4
YZR
Sarnia
PHN
YXU
London
ALV
DTX
RTK
MTC
SOM
LAR
16015
CRO
VLL
Lake St. Clair
45132
DET
45147
LSCM4
LSC
BEA
13001
PAI
PAL
XRG
Detroit
Windsor
YQG
12018
LIG
MER
WAJ
ARB
YIP
DTW
12059
WOO
PAQ
STA
COT
KONZ
WHE
XHA
LEA
IADN
XPT
TTF
THLO1
65135
WNB
Lake Erie
DUH
THRO1
CMPO1
Toledo
SBO1
45005
MRHO1
TDZ
BKL
CGF
Cleveland
LPR
CLE
LEGEND
0
30 km
Existing operational met stn
Existing OME AQ + met stn
EC AQ supersite + met stn
Univ AQ supersite + met stn + profiles
EC ATMOS met stn + AQ
YorkU ATMOS met stn
EC buoy met stn
EC buoy AQ + met stn
WSO radar stn
CLE radar stn + met stn
DTX radar stn + rawinsonde stn


2000
1000
0
Height (m)
Free
Atmosphere
CAPPING INVERSION
ENTRAINMENT ZONE
Residual / Return
Flow Layer
LCL
LCL
Convective
Mixed
Layer
CAPPING INVERSION
Stable / Inflow Layer
TIBL
Lake
Breeze
Front
Lake
Land
Horizontal Distance

Experimental design

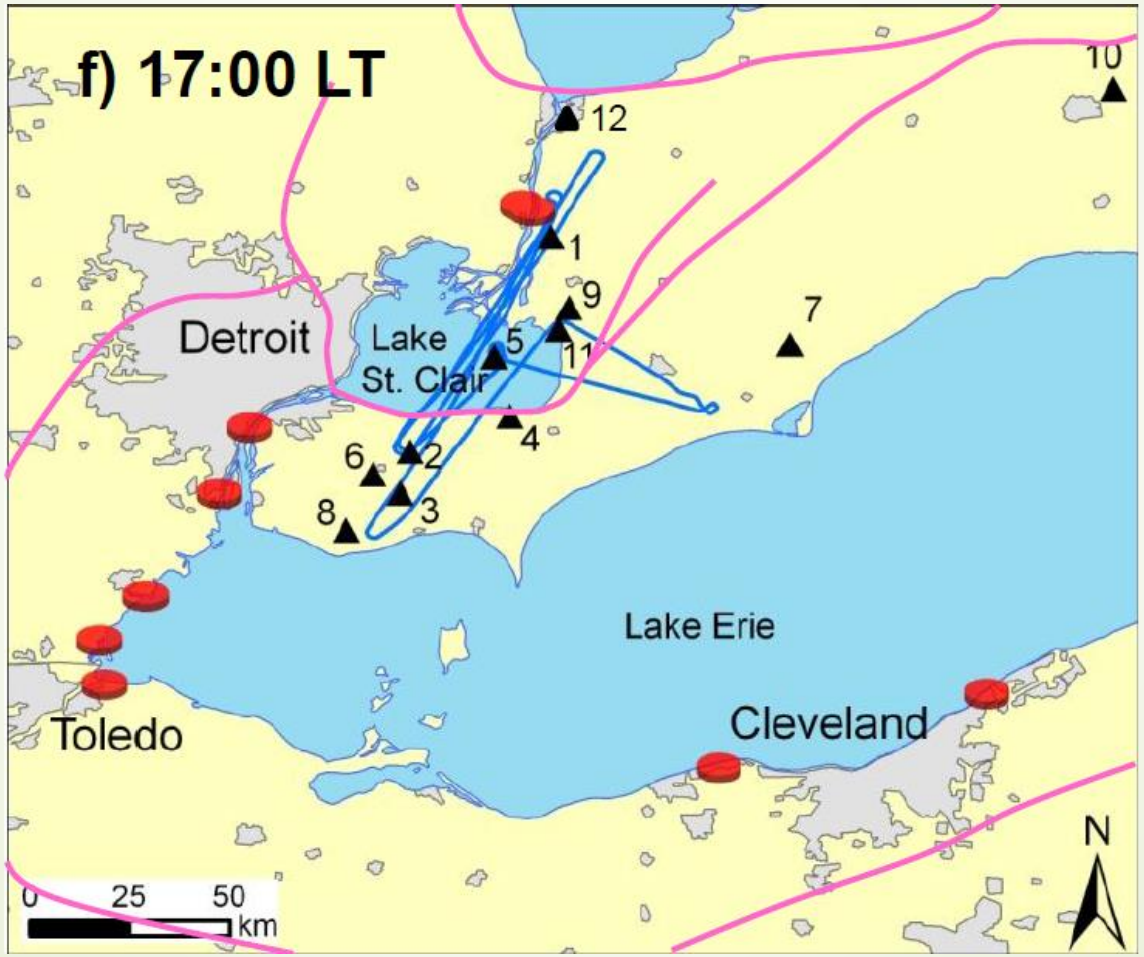


Table 1. Summary of Twin Otter flights showing the synoptic wind direction (based on back-trajectories analyses), an air quality descriptor (AQ), the lake breeze type (LD = Low Deformation; MD= Medium Deformation; HD=High Deformation; details in Sills et al., 2011), and O_3 and SO_4^{2-} mean and maximum levels based on aircraft measurements.

Flt #	Date	Takeoff Time (LT)	Landing Time (LT)	Flight Duration (hh:mm)	Synoptic Wind Direction	AQ/Source Region	Lake Breeze Type	$[O_3]$ (ppbv)		$[SO_4^{2-}]$ ($\mu g\,m^{-3}$)	
								Mean	Max	Mean	Max
1	23 June	8:52	11:15	02:23	Northwest	Good/Local sources	LD	32.3	39.2	0.14	0.33
2	23 June	13:30	15:57	02:27	Northwest	Good/Local sources	LD	39.9	57.7	0.34	1.89
3	23 June	17:43	18:16	00:33	Northwest	Good/Local sources	LD	40.0	47.4	0.39	0.74
4	25 June	11:01	13:24	02:23	Southwest	Poor/Local sources	LD	64.9	84.1	4.70	15.13
5	25 June	15:37	17:56	02:19	Southwest	Poor/Local sources	LD	73.0	105.5	6.92	29.07
6	25 June	19:13	20:07	00:54	Southwest	Poor/Local sources	LD	71.8	84.1	7.79	10.72
7	26 June	08:46	11:06	02:20	Southwest	Poor/Long range transport	MD	67.5	87.2	6.00	25.51
8	26 June	13:26	15:06	01:40	Southwest	Poor/Long range transport	MD	71.3	93.3	4.35	14.89
9	26 June	16:16	18:20	02:04	Southwest	Poor/Long range transport	MD	70.3	93.2	4.81	18.59
10	27 June	08:43	09:43	01:00	West	Detroit outflow	HD	43.3	65.8	2.18	9.73
11	27 June	11:17	13:41	02:24	West	Detroit outflow	HD	62.9	85.2	2.98	8.20
12	3 July	19:00	21:30	02:30	South then north	Poor/Long range transport	MD	66.2	102.6	2.32	11.78
13	7 July	04:35	07:17	02:42	Northwest	Detroit outflow	MD	45.4	79.0	0.56	1.87
14	7 July	13:44	16:20	02:36	Northwest	Detroit outflow	MD	63.6	87.2	0.75	3.53
15	8 July	11:36	14:14	02:38	West	Detroit outflow	HD	66.5	87.2	2.47	7.41
16	8 July	18:32	21:00	02:28	West	Detroit outflow	HD	69.8	81.0	2.36	4.65

Table 2. Summary of trace gas and particle instrumentation on the Twin Otter aircraft.

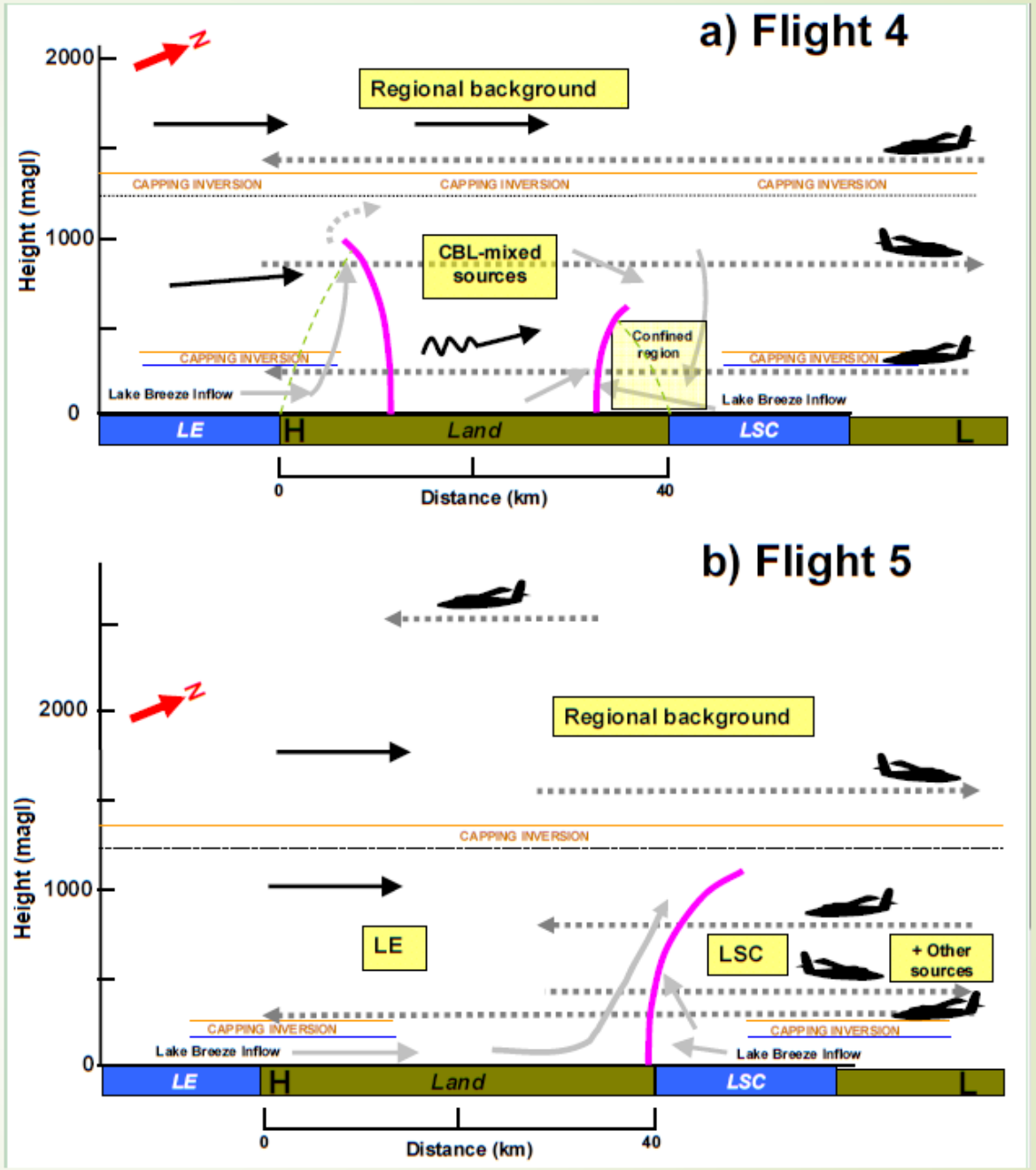
Measurement	Principle of Operation	Instrument	Resolution (s)
Particle composition	aerosol mass spectrometry/time of flight detection	Aerodyne C-AMS	30
O_3	UV absorption	TECO 49	5
CO	VUV resonance fluorescence	Aerolaser	1
SO_2	UV fluorescence	TECO 43S	10
NO/NO_2	chemiluminescence, photolysis	TECO 42S	20, alternating
Particle number	light scattering	TSI 7610 CNC	1
Particle size distribution (0.120–2 μm)	light scattering	PCASP (passive cavity aerosol spectrometer probe)	1
Black carbon	light absorption	PSAP (particle soot absorption photometer)	1

Model description

- The Unified Regional Air-quality Modelling System (AURAMS) model was used to support the BAQS-Met field study.

- The model has three main components: (1) a prognostic meteorological model GEM (Global Environmental Multiscale model); (2) an emissions processing system; and (3) an off-line regional chemical transport model, the AURAMS Chemical Transport Model.

Results and discussion



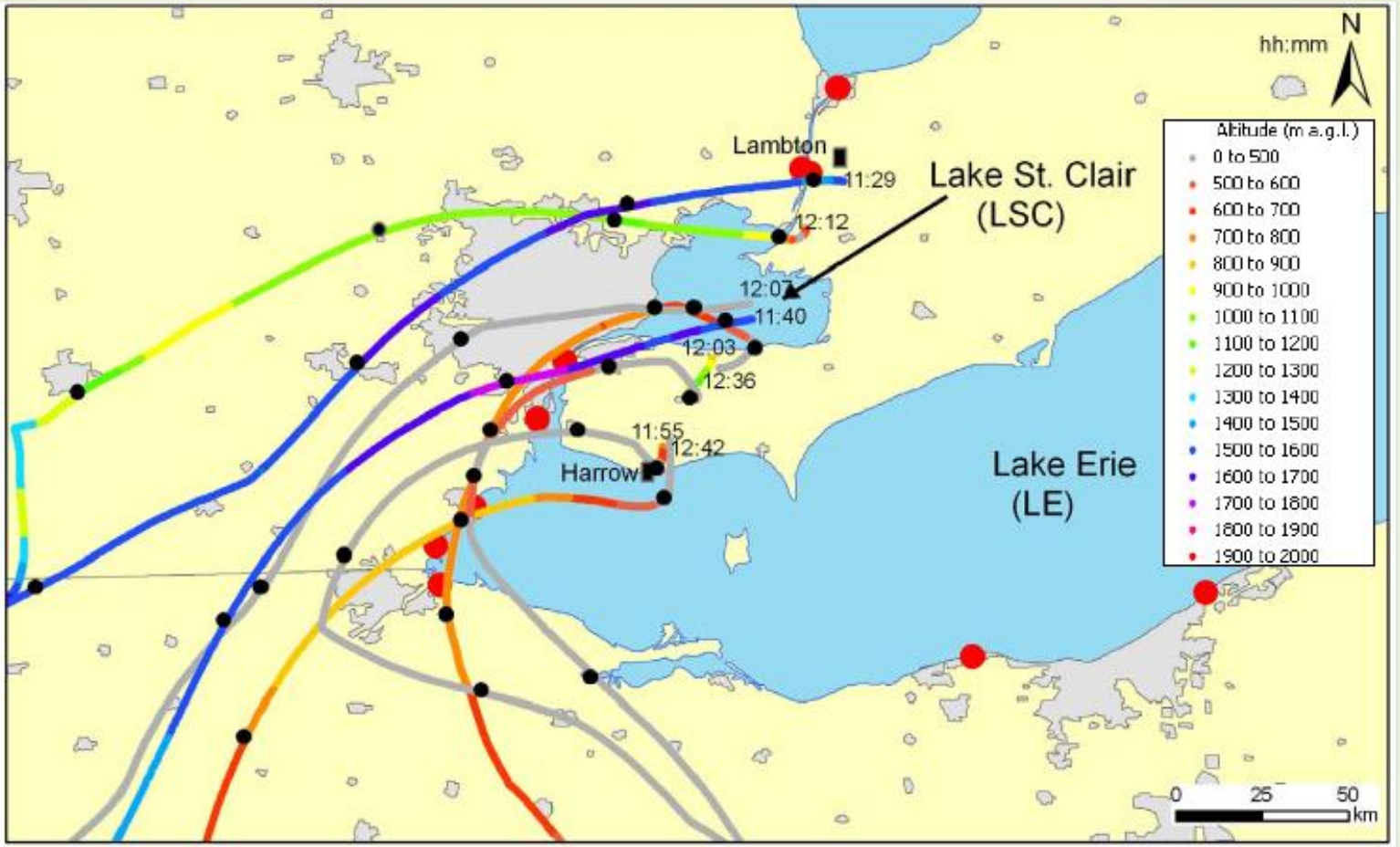


Fig. 1. High resolution back trajectories for 25 June arriving at selected locations and times along the Flight 4 aircraft track. Arrival times indicated as hh:mm. Trajectories are coloured by altitude (m a.g.l.). Black circles along trajectories every 4 h . SO_2 point sources shown as red circles (SO_2 >10 000 tons/year).

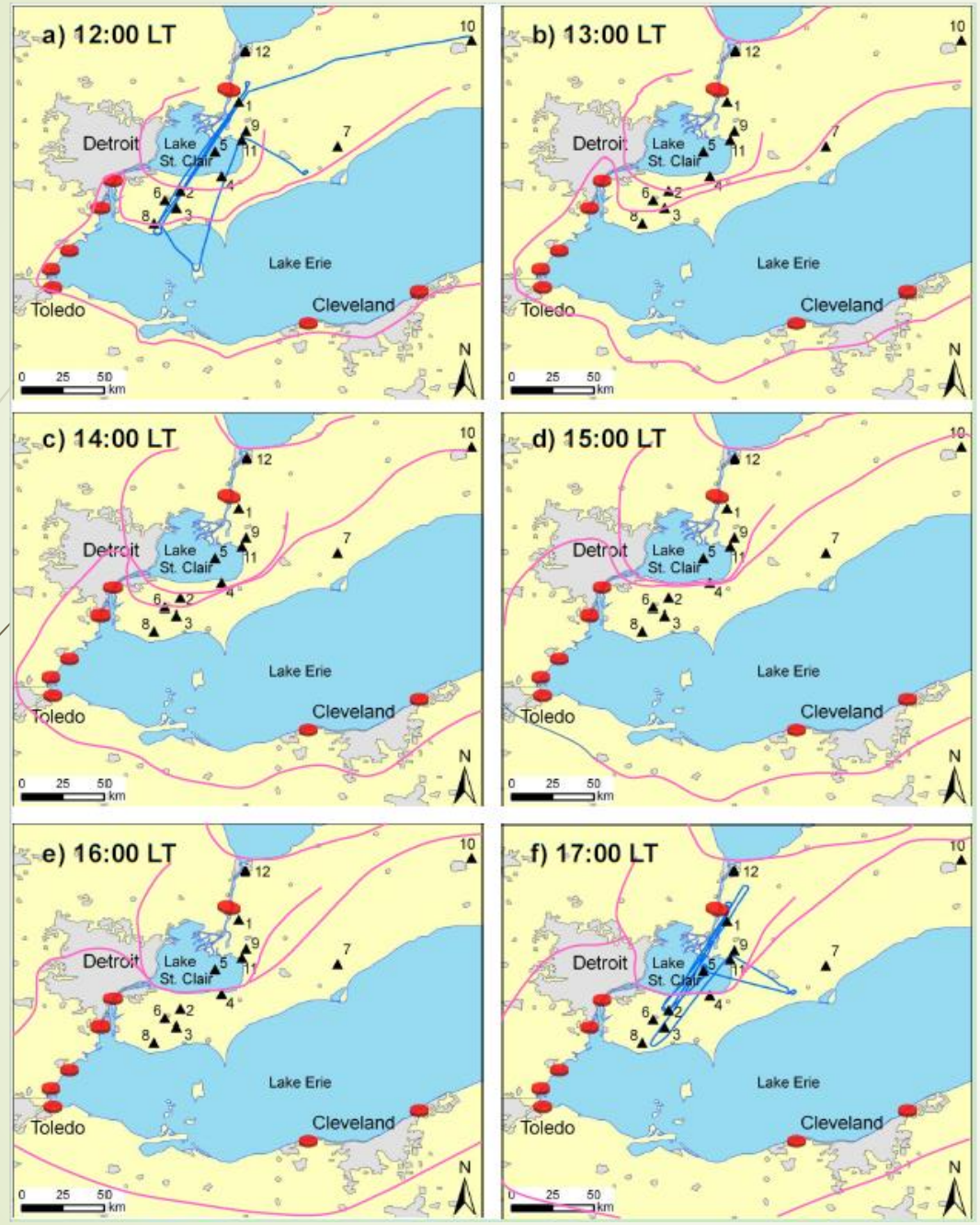
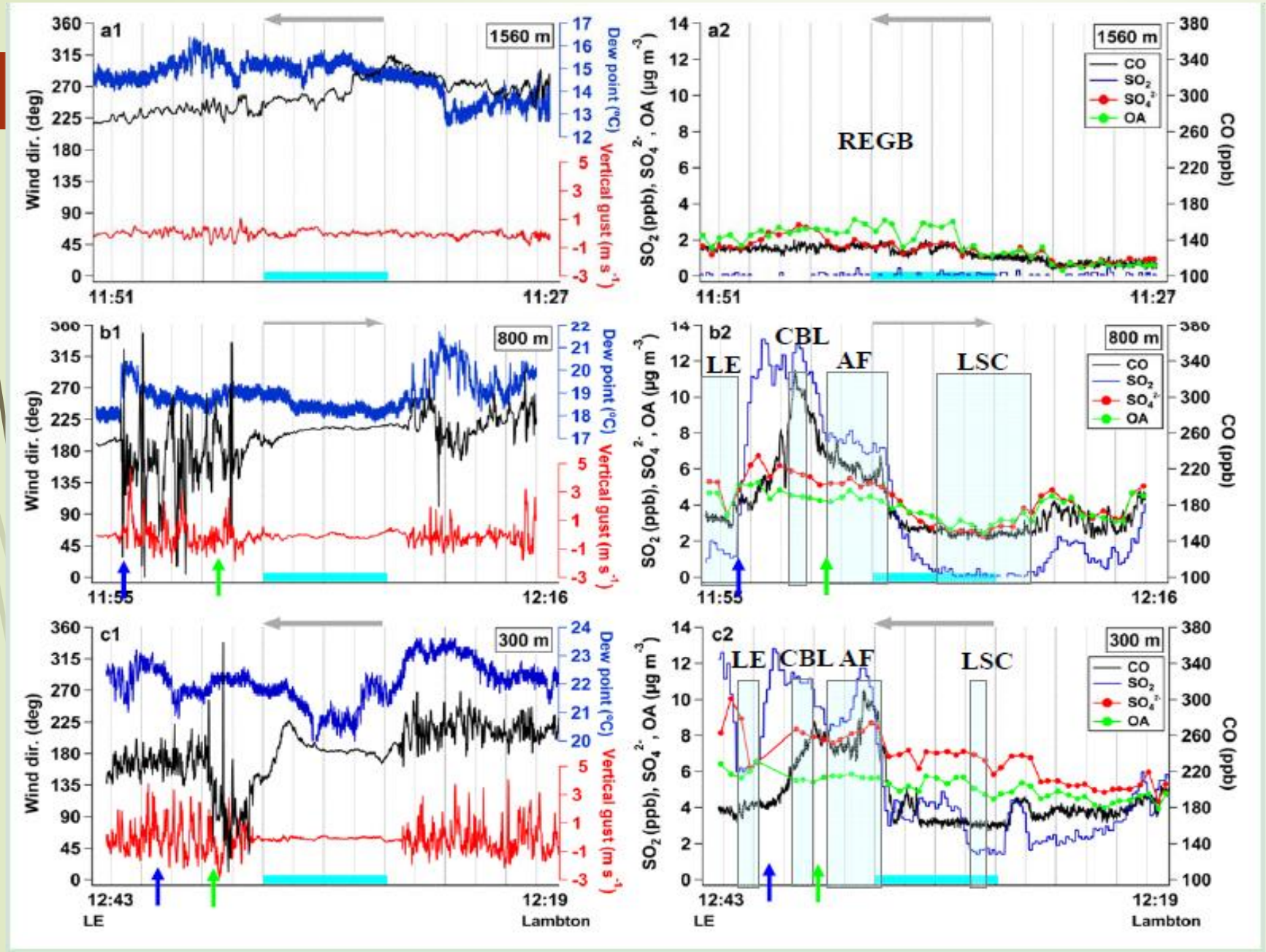


Fig. 2. Progression of lake-breeze fronts from 12:00–17:00 LT on 25 June. Position of lake-breeze fronts shown in magenta lines. Tracks for Flights 4 and 5 are shown as blue lines in **(a)** and **(f)** respectively. SO_2 major point sources shown as red circles (SO_2 >10 000 tons/year). Surface sites in black triangles: (1) Sombra, (2) Woodslee, (3) Cottam, (4) Lighthouse Cove, (5) LSC buoy, (6) Essex, (7) Ridgetown, (8) Harrow, (9) Bear Creek, (10) London, (11) Mitchell's Bay, (12) Sarnia


a1
1560 m
Wind dir. (deg)
Dew point (°C)
Vertical gust (m s-1)
11:51
11:27
a2
REGB
CO
SO2
SO4 2-
OA
SO2 (ppb), SO4 2-, OA (μg m-3)
CO (ppb)
b1
800 m
11:55
12:16
b2
LE
CBL
AF
LSC
c1
300 m
12:43
12:19
LE
Lambton
c2

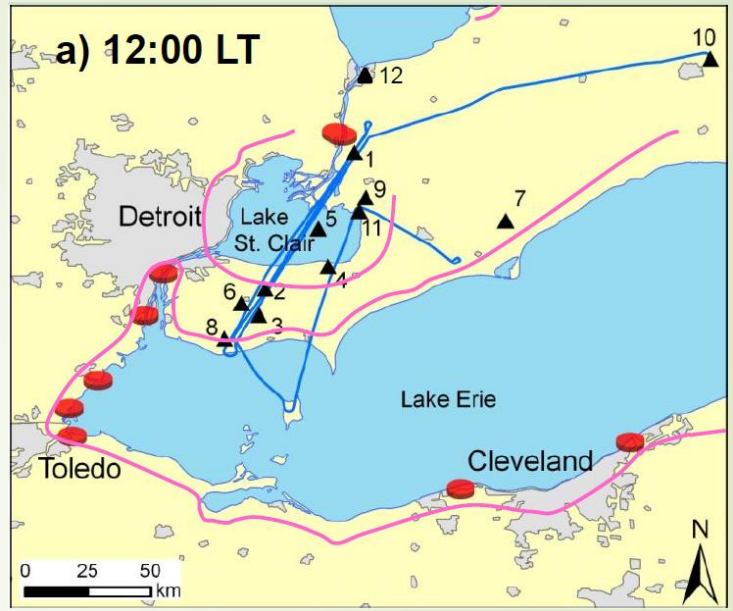
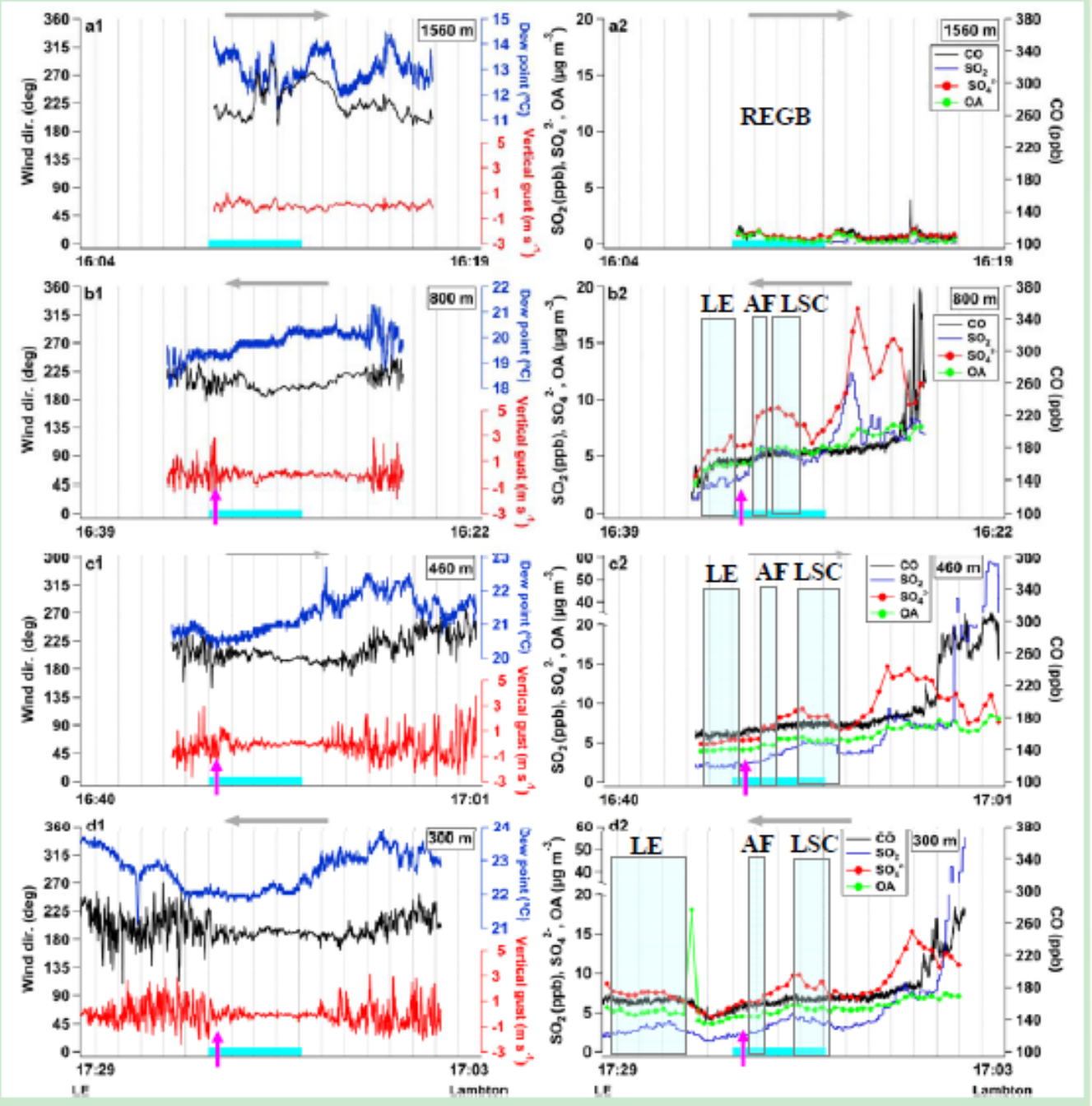

a) 12:00 LT
Detroit
Lake St. Clair
Lake Erie
Toledo
Cleveland
N
0 25 50
km

Fig. 3.


a1
1560 m
Wind dir. (deg)
Dew point (°C)
Vertical gust (m s-1)
16:04
16:19
a2
REGB
SO2 (ppb), SO4 2-, OA (μg m-3)
CO (ppb)
CO
SO2
SO4 2-
OA
b1
300 m
16:39
16:22
b2
LE AF LSC
c1
460 m
16:40
17:01
c2
d1
300 m
17:29
17:03
d2
LE
AF
LSC
Lambton

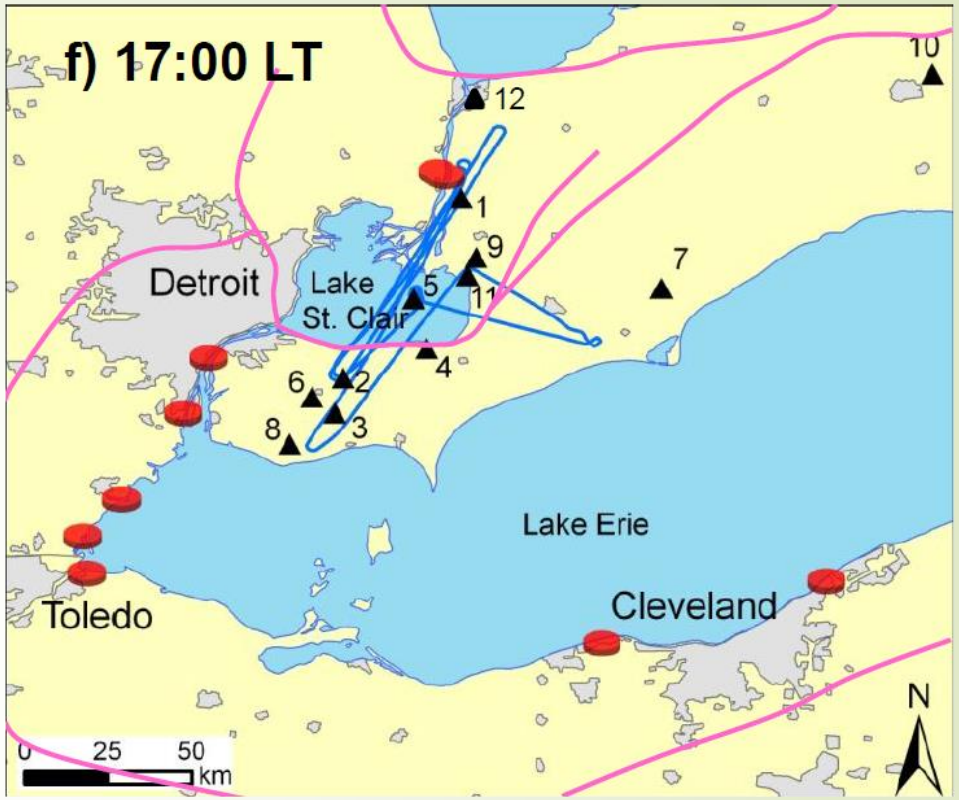

f) 17:00 LT
Detroit
Lake
St. Clair
Lake Erie
Toledo
Cleveland
1
2
3
4
5
6
7
8
9
10
11
12
0
25
50
km
N

Fig. 4.

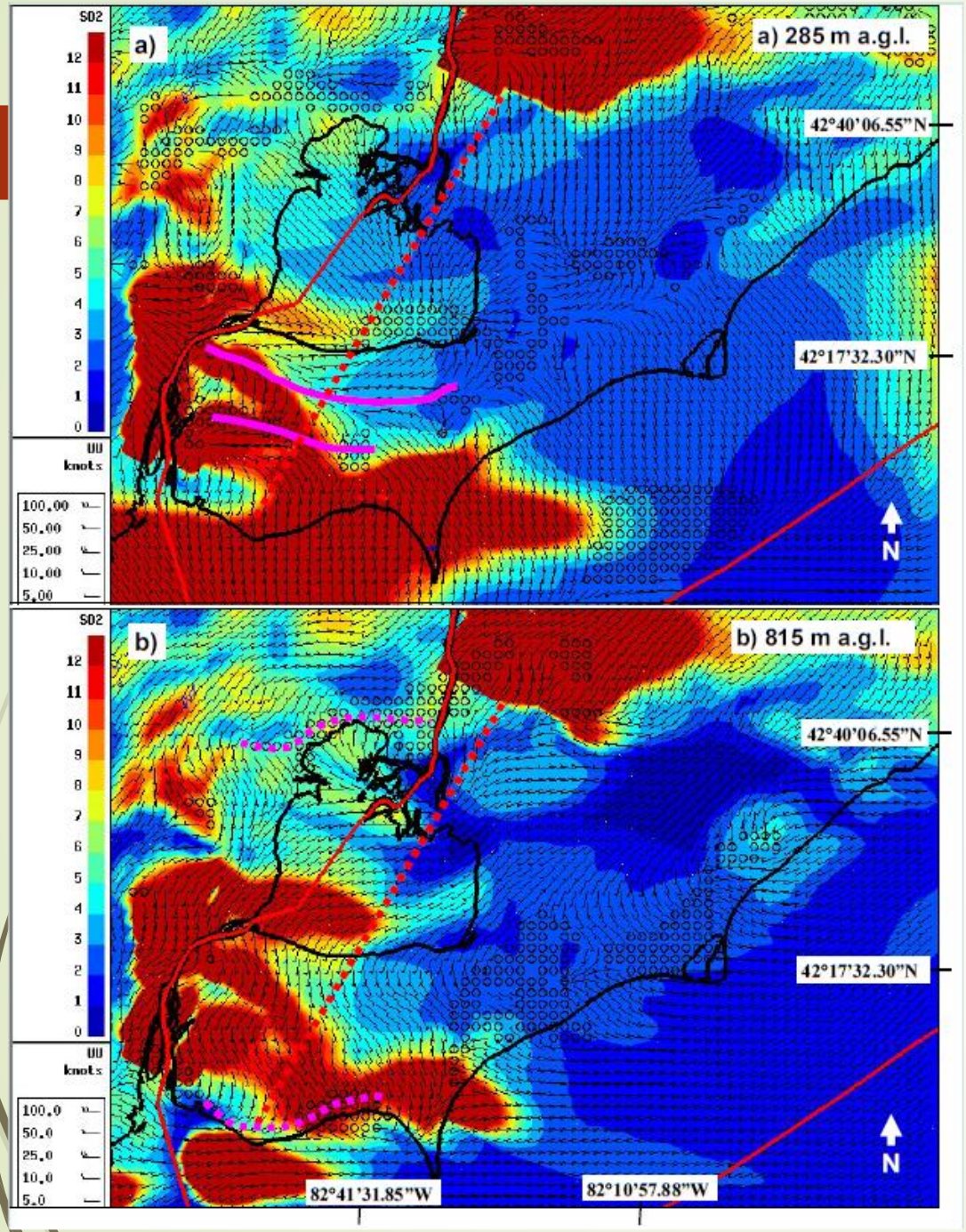


Fig. 5. Model-predicted SO_2 mixing ratios overlaid with wind direction at **(a)** 285ma.g.l. and **(a)** 815ma.g.l at 12:00 LT. Solid magenta line indicates surface convergence at the LE and LSC lake breeze fronts and dashed magenta line indicates divergence flow aloft. Dashed red line is the aircraft transect.

Conclusions

- This was based upon two aircraft flights (Flights 4 and 5 on 25 June 2007) in southwestern Ontario where horizontal transects across the entire lake-breeze circulation at multiple altitudes were performed.

- Observations and modelling support the interpretation of a lake-breeze circulation where pollutants were lofted at a lake-breeze front, transported in the synoptic flow, caught in a downdraft over the lake, and then confined by onshore flow.

Thank you