

Ground-air gas emission rate inferred from measured concentration rise, within a disturbed atmospheric surface layer*

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*J. Appl. Meteor. Climatol. 49, 2010

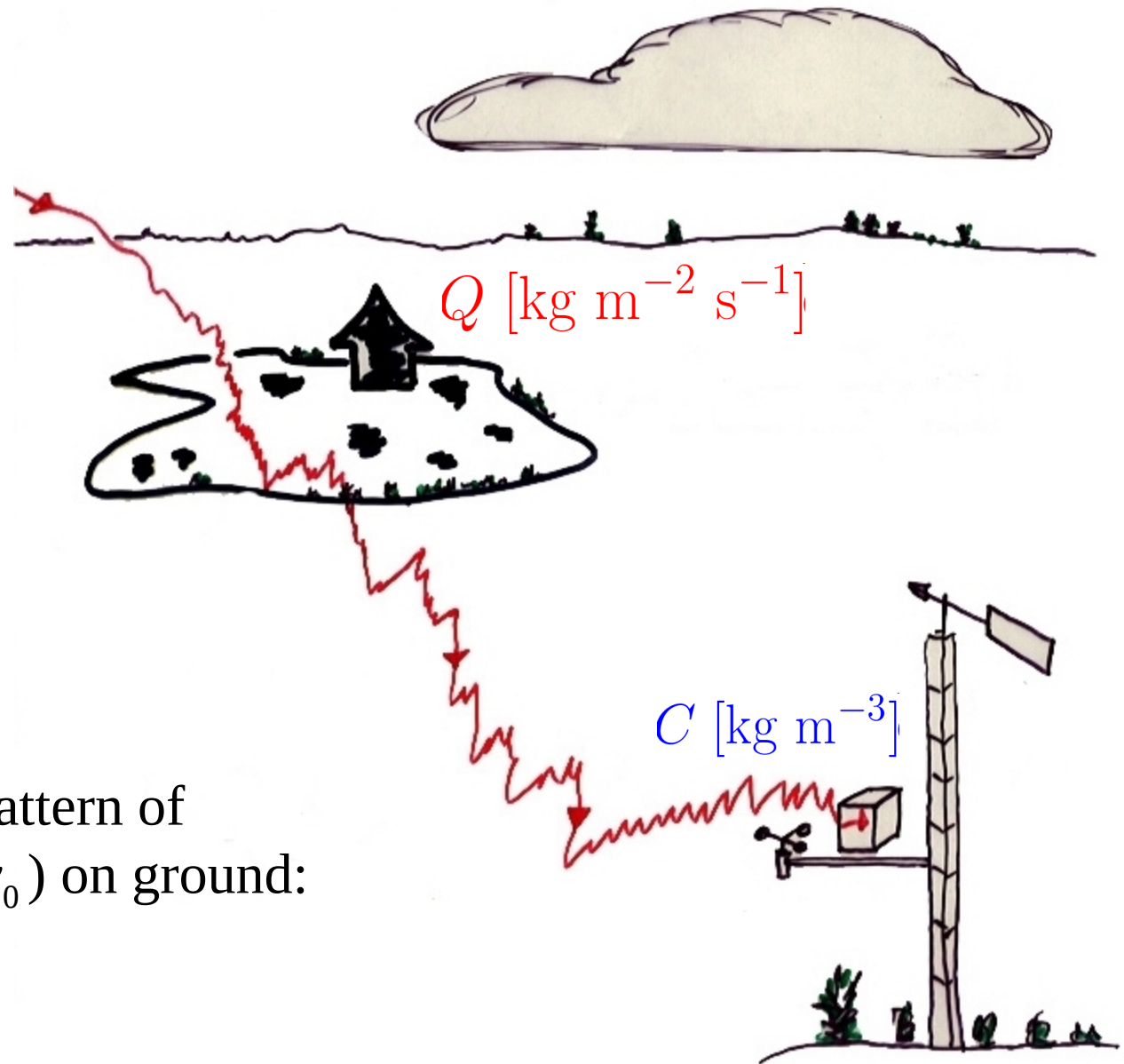
- in undisturbed winds we have a well-tryed means to compute an ensemble of forward (f) or backward (b) paths

- this is encoded in WindTrax, which assumes Monin-Obukhov profiles for all needed properties, thus: “**MO-bLS**”

- the **C** - **Q** rel'n hinges on pattern of “touchdowns” (vert veloc. w_0) on ground:

$$\frac{C}{Q} = \frac{1}{N_P} \sum \frac{2}{|w_0|}$$

- compute NP paths; sum over all touchdowns within source



Inverse dispersion by computing N_p backward paths to source(s)

bLS applied to determine methane emission from waste lagoons

Inverse dispersion using bLS to determine methane emission rate from a lagoon

Sonic anemometer provides wind statistics (15 min intervals)

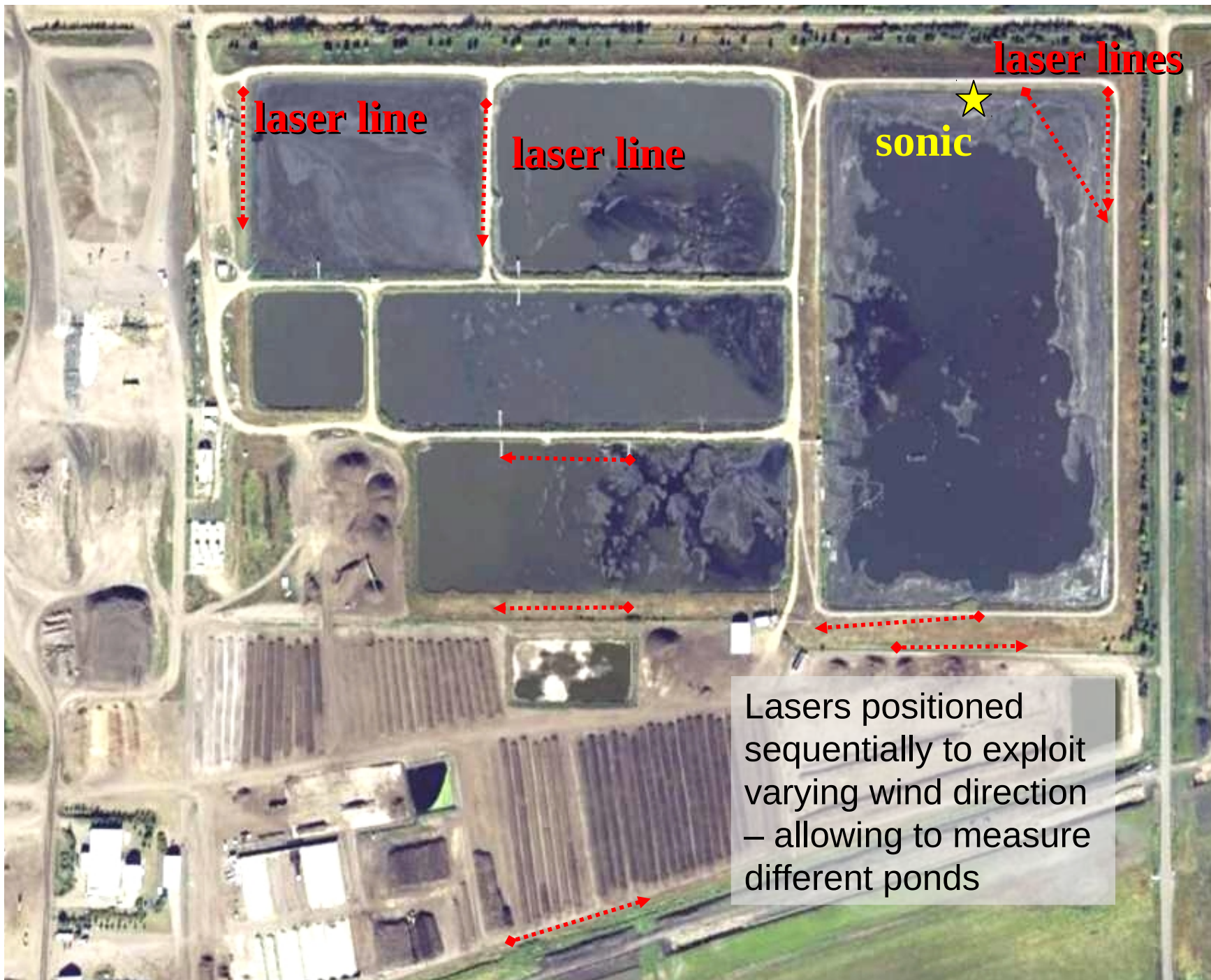


bLS applied to determine methane emission from waste lagoons

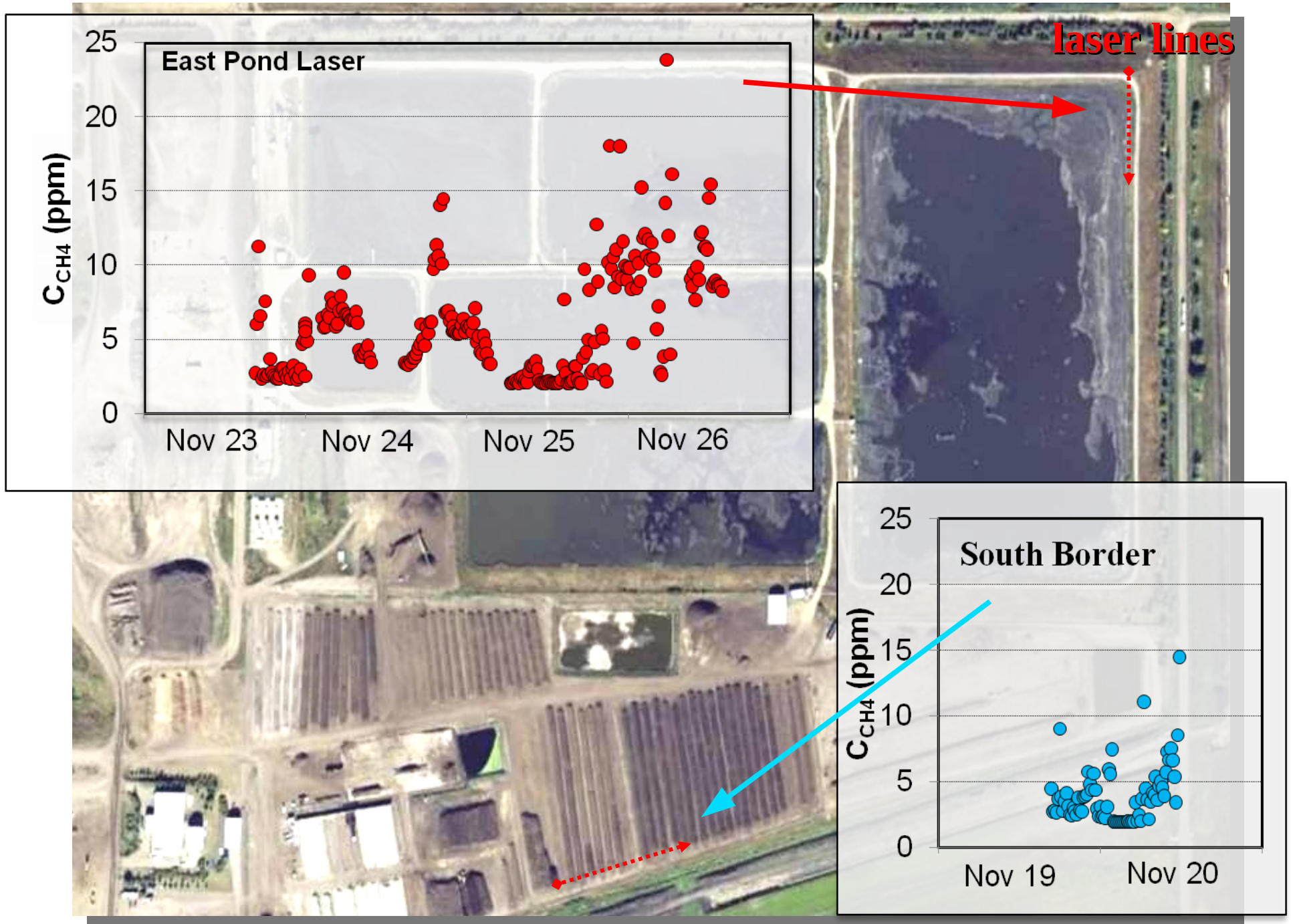


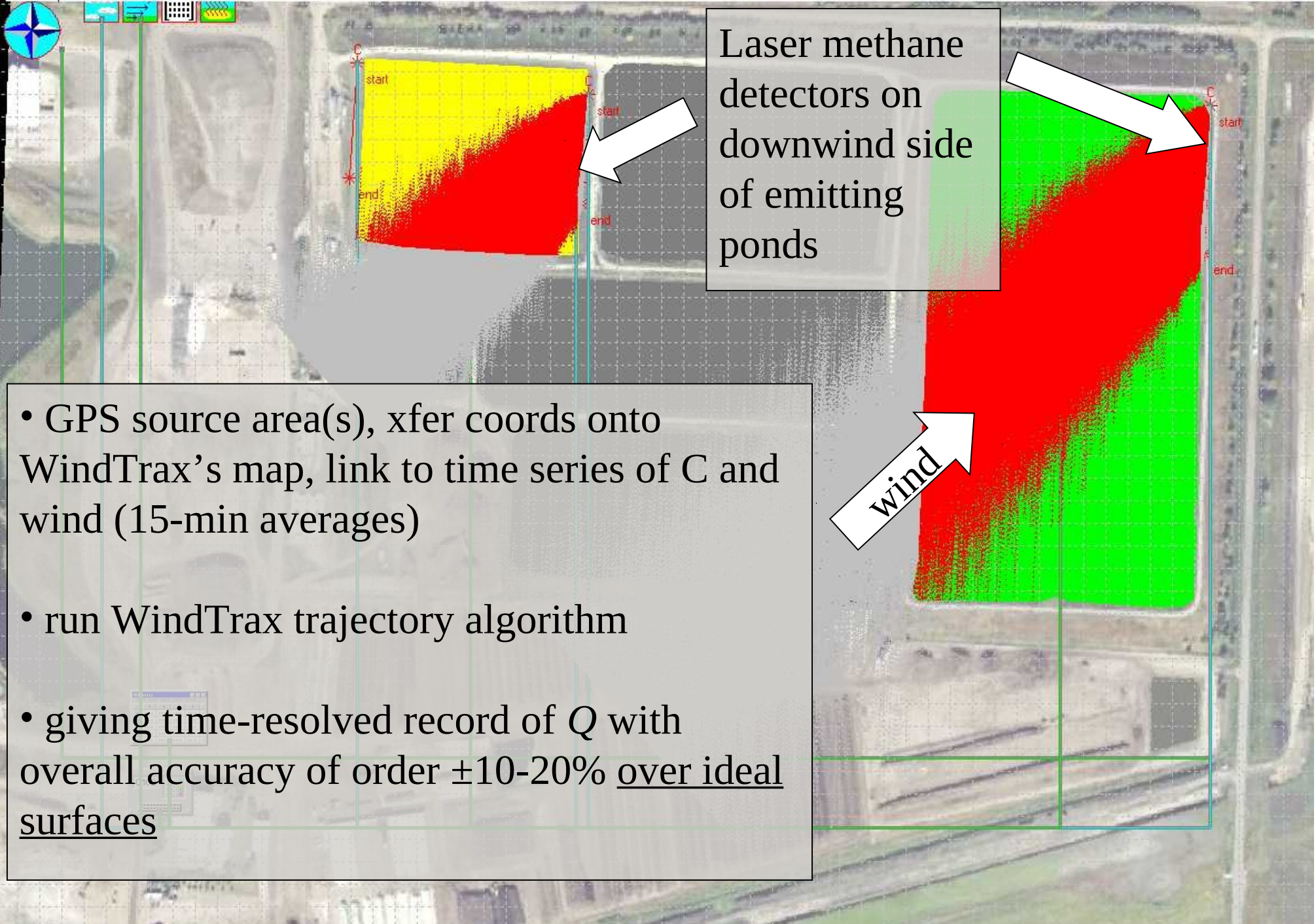
Line-averaging laser methane detector
(pathlength typically ~ 100 m)

bLS applied to determine methane emission from waste lagoons



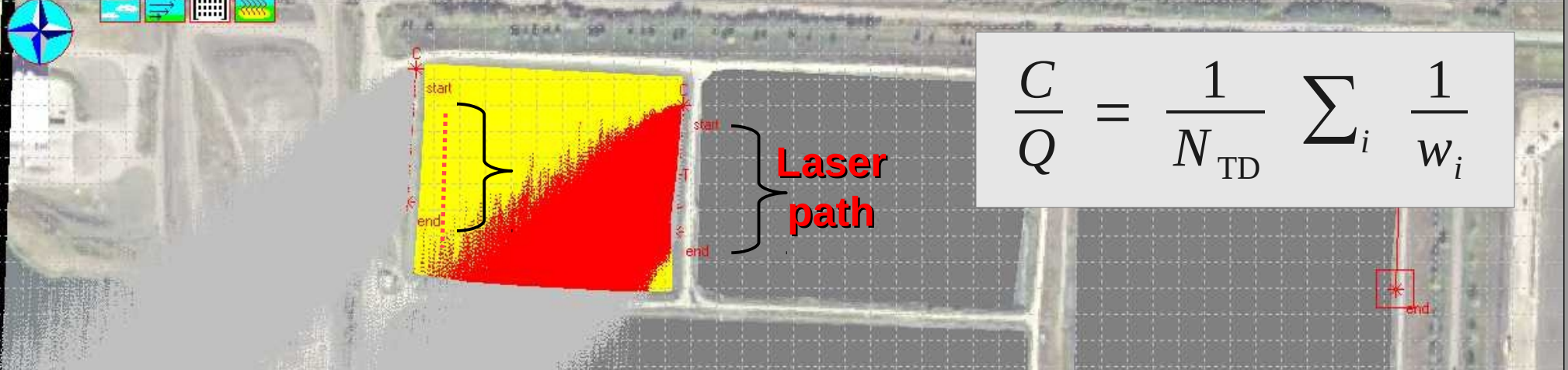
Concentration signals – not necessarily time-continuous





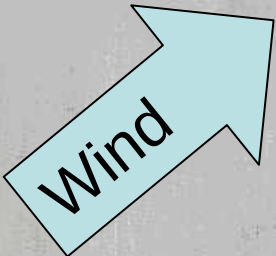
Converting concentration (C) to emission rate (Q) using WindTraX

Recent input data: 328.125 328.300 1.19 -1.05 0.23 1.59 228 1.63 228 0.15 2.2 2.66 1.13 0.013748 -0.62 0.6 -386.1 -0.0026 14.2 328.125 222.03 2.34 1 222.03 2.337157895 34 98 95 5584 5635 2009 11 24 3 0 CH40P-1014 4001 328.1251 260.74 2.9



$$\frac{C}{Q} = \frac{1}{N_{TD}} \sum_i \frac{1}{w_i}$$

Touchdowns (red on source, grey elsewhere): air in contact with surface at these points eventually passes through laser beam



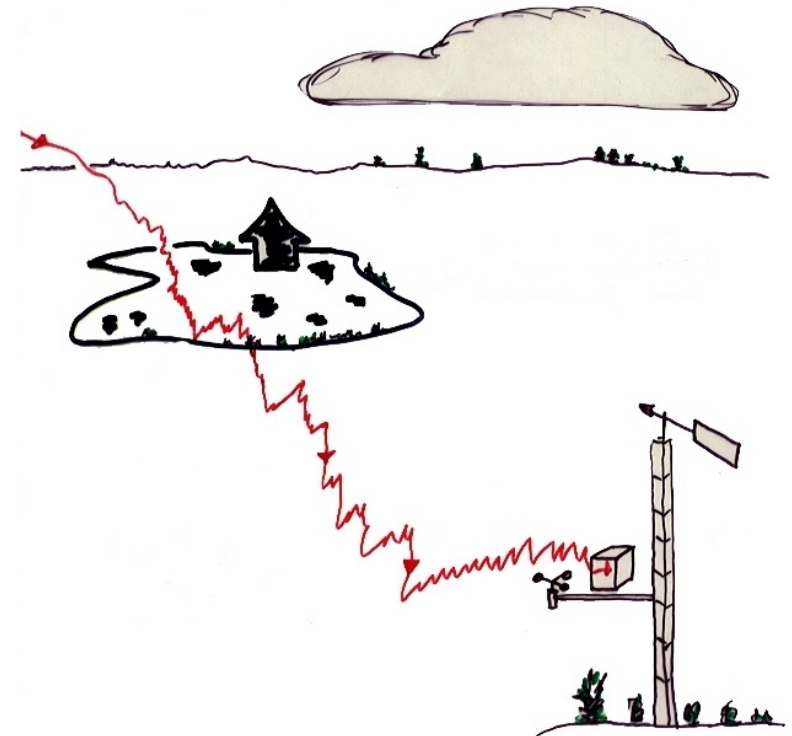
- Time = 3 am, Nov. 24, 2009
 - $C_{west} = 2.34$ ppm
 - $C_{east} = 2.83$ ppm (well above “background”)
 - Windspeed = 1.6 m/s
 - Atmos. weakly unstable
- Emission Rate: $Q = 1.7$ kg/hr (total)**

Time	Concentration
00:00	0.00
00:05	0.00
00:10	0.00
00:15	0.00
00:20	0.00
00:25	0.00
00:30	0.00
00:35	0.00
00:40	0.00
00:45	0.00
00:50	0.00
00:55	0.00
01:00	0.00
01:05	0.00
01:10	0.00
01:15	0.00
01:20	0.00
01:25	0.00
01:30	0.00
01:35	0.00
01:40	0.00
01:45	0.00
01:50	0.00
01:55	0.00
02:00	0.00
02:05	0.00
02:10	0.00
02:15	0.00
02:20	0.00
02:25	0.00
02:30	0.00
02:35	0.00
02:40	0.00
02:45	0.00
02:50	0.00
02:55	0.00
03:00	2.34
03:05	2.34
03:10	2.34
03:15	2.34
03:20	2.34
03:25	2.34
03:30	2.34
03:35	2.34
03:40	2.34
03:45	2.34
03:50	2.34
03:55	2.34
04:00	2.34
04:05	2.34
04:10	2.34
04:15	2.34
04:20	2.34
04:25	2.34
04:30	2.34
04:35	2.34
04:40	2.34
04:45	2.34
04:50	2.34
04:55	2.34
05:00	2.34

0.102

MO-bLS method for inferring emission rate

- convenient; provides a time-resolved (but typically non-continuous) record with overall accuracy that should be of order +/- 10%
- provides an average of emission rate over a large surface area
- requires
 - well defined background (use a second sensor to determine this?)
 - that source area(s) can be delineated from non-source



Ammonia emission from lagoons

S. M. McGinn¹, T. C. ...

¹Agriculture and Agri-Food Canada, 540 ...
²Department of Earth and ...
³Thunder Bay ...

Estimating Gas Emissions from Multiple Sources Using a Backward Lagrangian Stochastic Model

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 Research Branch, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada

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 Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta, Canada

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Atmospheric Environment 39 (2005) 4863–4874

ATMOSPHERIC ENVIRONMENT

www.elsevier.com/locate/atmosenv

Estimating gas emissions from a farm with an inverse-dispersion technique

Thomas K. Flesch^{a,*}, John D. Wilson^b, Lowry A. Harper^b, Brian P. Crenna^a

^aEarth and Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada T6G 2G7

^bUSDA, Wildlife Services, USDA, Walkersville, GA, 30677, USA

22

Australia and Canada

Estimating Tracer Emissions with a Backward Lagrangian Stochastic Technique

THOMAS K. FLESCHE AND JOHN D. WILSON

University of Alberta
 Edmonton, Canada

Common micrometeorological techniques (e.g., eddy covariance, flux chamber, etc.) are used to estimate emissions from a point source.

Methane emissions from beef cattle – a comparison of paddock- and animal-scale measurements

Johannes Lambach^{a,*}, Francis M. Kelliher^b, Terry W. Knight^b, Harry Clark^c, Gordon Milne^d and Adriano Cavallari^e

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^cCorresponding author (email: lambach@lambachresearch.co.nz)

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European Journal of Agronomy 21 (2005) 1–9

Use of the backwards Lagrangian stochastic dispersion model for measuring ammonia emissions from a cattle feedlot

Thomas K. Flesch^{a,*}, John D. Wilson^b, Lowry A. Harper^b, Brian P. Crenna^a

^aEarth and Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada T6G 2G7

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Agricultural and Forest Meteorology 129 (2005) 137–150

The evaluation of a backward Lagrangian stochastic (bLS) model to estimate greenhouse gas emissions from a cattle feedlot

Thomas K. Flesch^{a,*}, John D. Wilson^b, Lowry A. Harper^b, Brian P. Crenna^a

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Agricultural and Forest Meteorology 129 (2005) 137–150

Measuring methane emission rates of a dairy cow herd (II): results from a backward-Lagrangian stochastic model

Johannes Lambach^{a,*}, Francis M. Kelliher^b

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^bAgResearch, Private Bag 11000, Palmerston North 4442, New Zealand

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Energy Procedia 1 (2005) 2407–2414

Measuring Ammonia Emissions from a Cattle Feedlot using a Dispersion Model

Thomas K. Flesch^{a,*}, John D. Wilson^b, Lowry A. Harper^b, Brian P. Crenna^a

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Atmospheric Monitoring and Verification Technologies for CO₂ Geosequestration

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^bCSIRO Marine and Atmospheric Research, PMB, Aspendale, Victoria 3195, Australia

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Agricultural and Forest Meteorology 140 (2005) 1136–1153

Atmospheric Monitoring for the Pembina Cardium CO₂ Monitoring Project using Open Path Laser Technology

Stephanie Tronier^{a,*}, William D. Gerner^a, Bernice Kadatz^a, Mark Olson^a, Ernie H. Peckins^a

^aEarth and Atmospheric Sciences, University of Alberta, Edmonton, AB, Canada T6G 2G7

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Atmospheric Environment 39 (2005) 4863–4874

Assessment of the backward Lagrangian Stochastic dispersion technique for continuous measurements of CH₄ emissions

Zhiling Gao^a, Matthias Mauder^b, Raymond L. Desjardins^a, Thomas K. Flesch^a, Ronald P. van Haarlem^a

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Agricultural and Forest Meteorology 140 (2005) 1136–1153

Testing Lagrangian atmospheric dispersion model leakage from geosequestration

Zoe Leeb^{a,*}, Ray Leuning^b, Steve Ziegler^b, David Etheridge^b

^aCSIRO Marine and Atmospheric Research, Centre for Australian Weather and Climate Research and CSIRO ...
^bCSIRO Marine and Atmospheric Research, Centre for Australian Weather and Climate Research and CSIRO ...

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The Effect of Biofuel Production on Swine Farm Methane and Ammonia Emissions

Lowry A. Harper^a, Lowry A. Harper Consulting Co., Swine Gas Emissions Consulting
 Thomas K. Flesch^b, University of Alberta
 Kim R. Weaver^c, Luthien Clark^c, University of Alberta
 John D. Wilson^d, University of Alberta

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MO-bLS as implemented in WindTrax neglects any disturbance to the wind... how serious in this approximation?

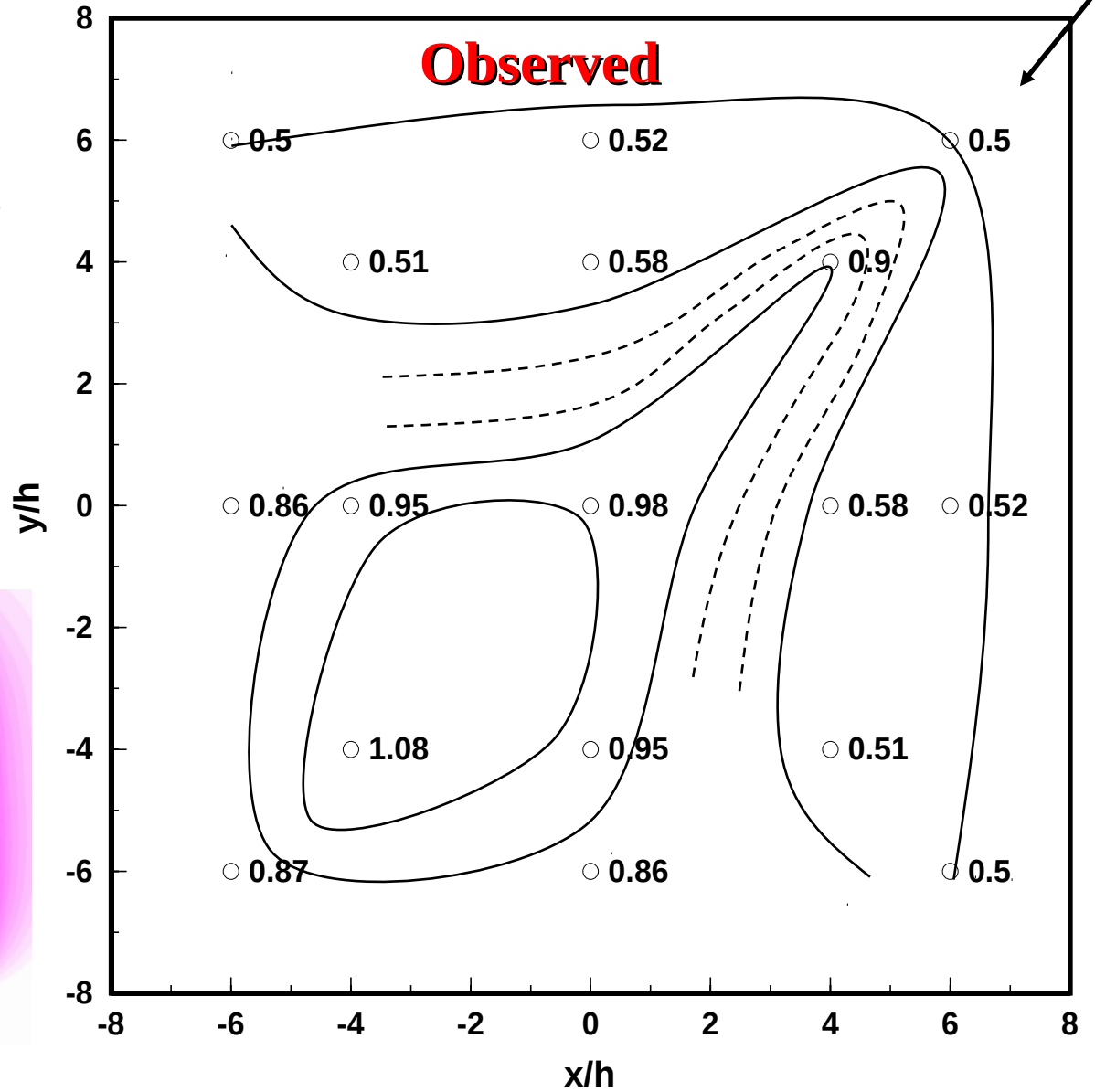
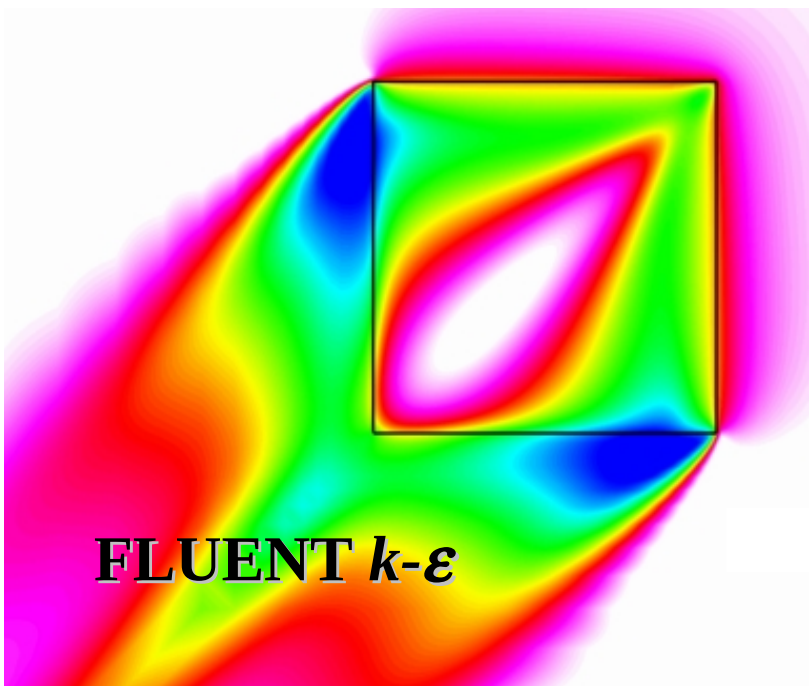
Trial gas release into “square plot” flow, for which computed 3D wind statistics “drive” a fully 3D LS model

- fence height $h = 1.25$ m
- side length 20 m ($16h$)

- methane from 6 m x 6 m source
- laser line-averaging gas detectors

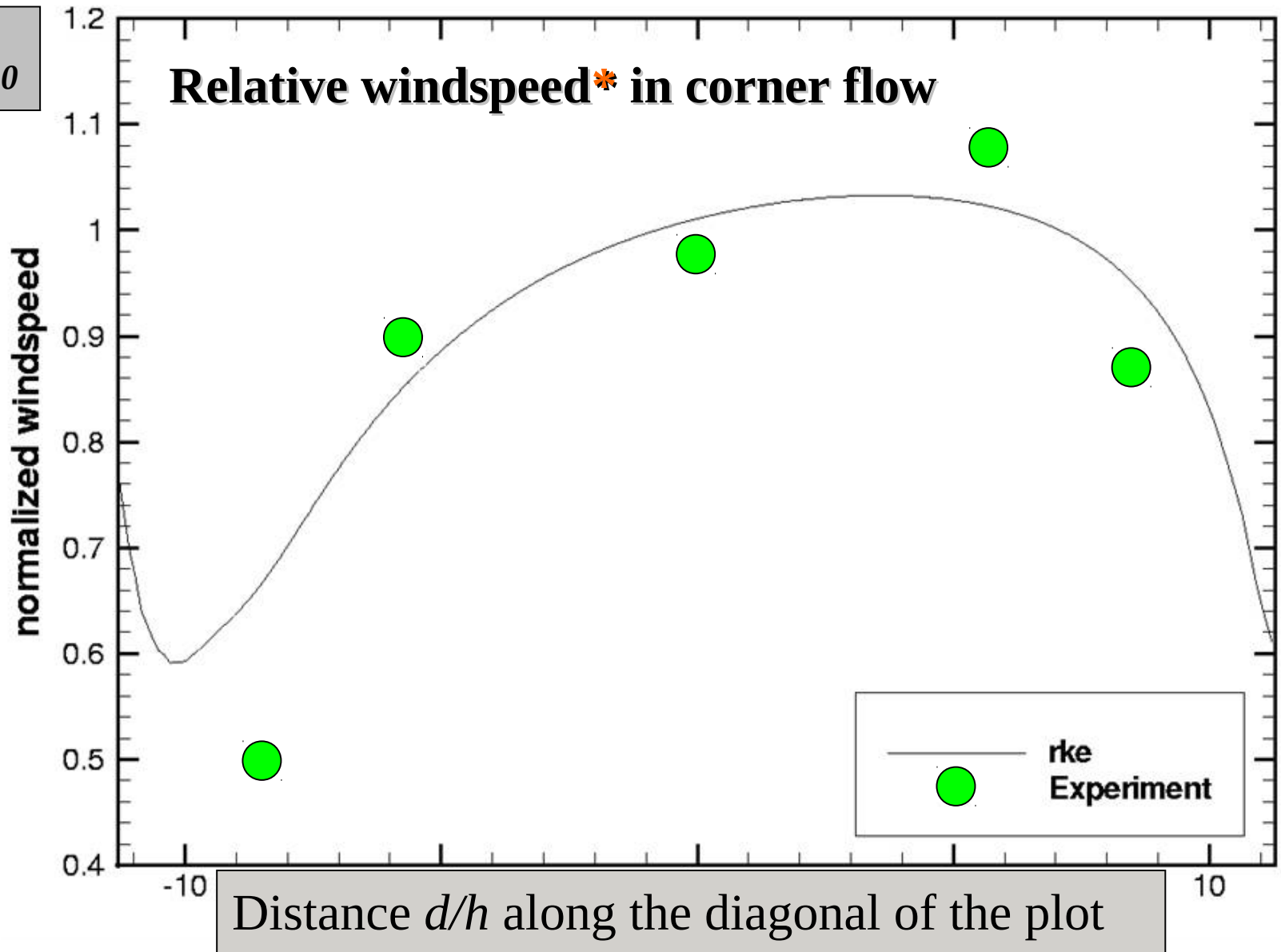
The square plot tracer dispersion trials

Contoured ratio S/S_0 of speed in plot at $h/2$ to speed at same height in open



Winds in the square plot *highly* disturbed

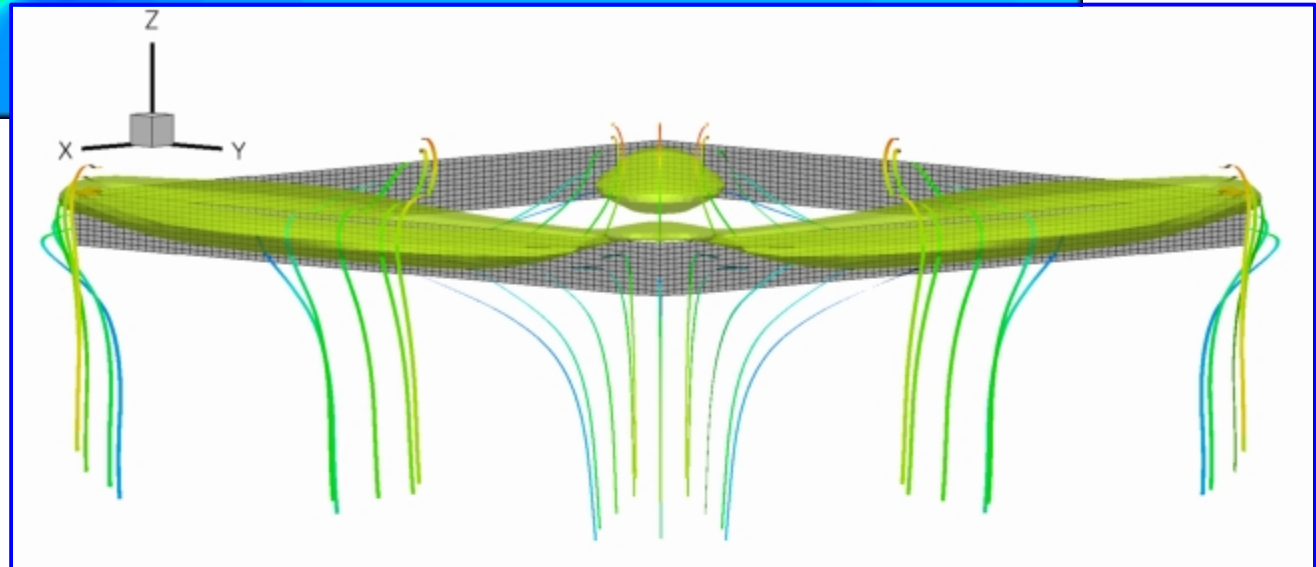
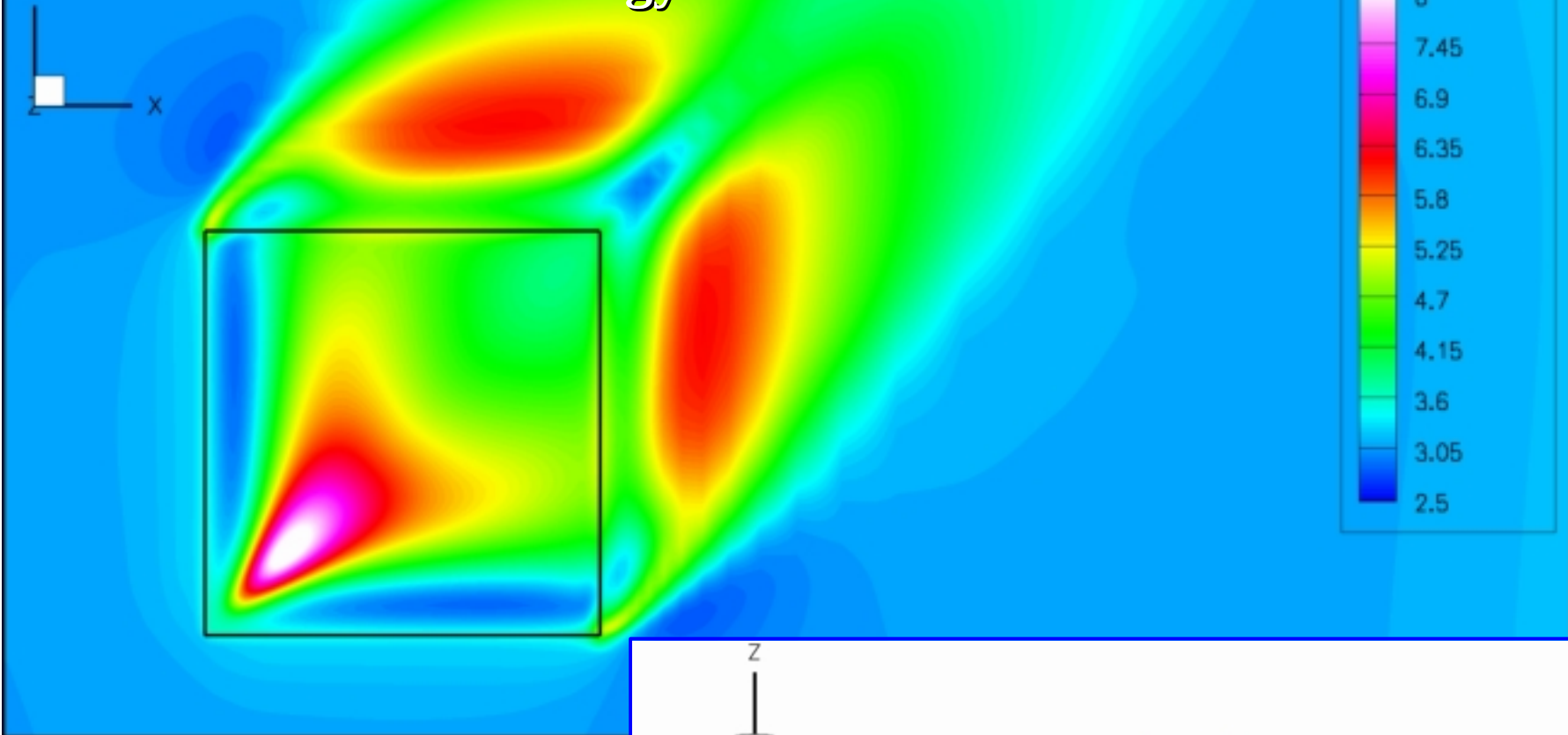
$$S/S_0$$



*ratio of speed in plot at $h/2$ to speed at same height in open

Quantitative comparison of FLUENT computation with measurements

Turbulent Kinetic Energy field at $h/2$



Computed pattern of TKE during corner flow

■ Tracer gas source

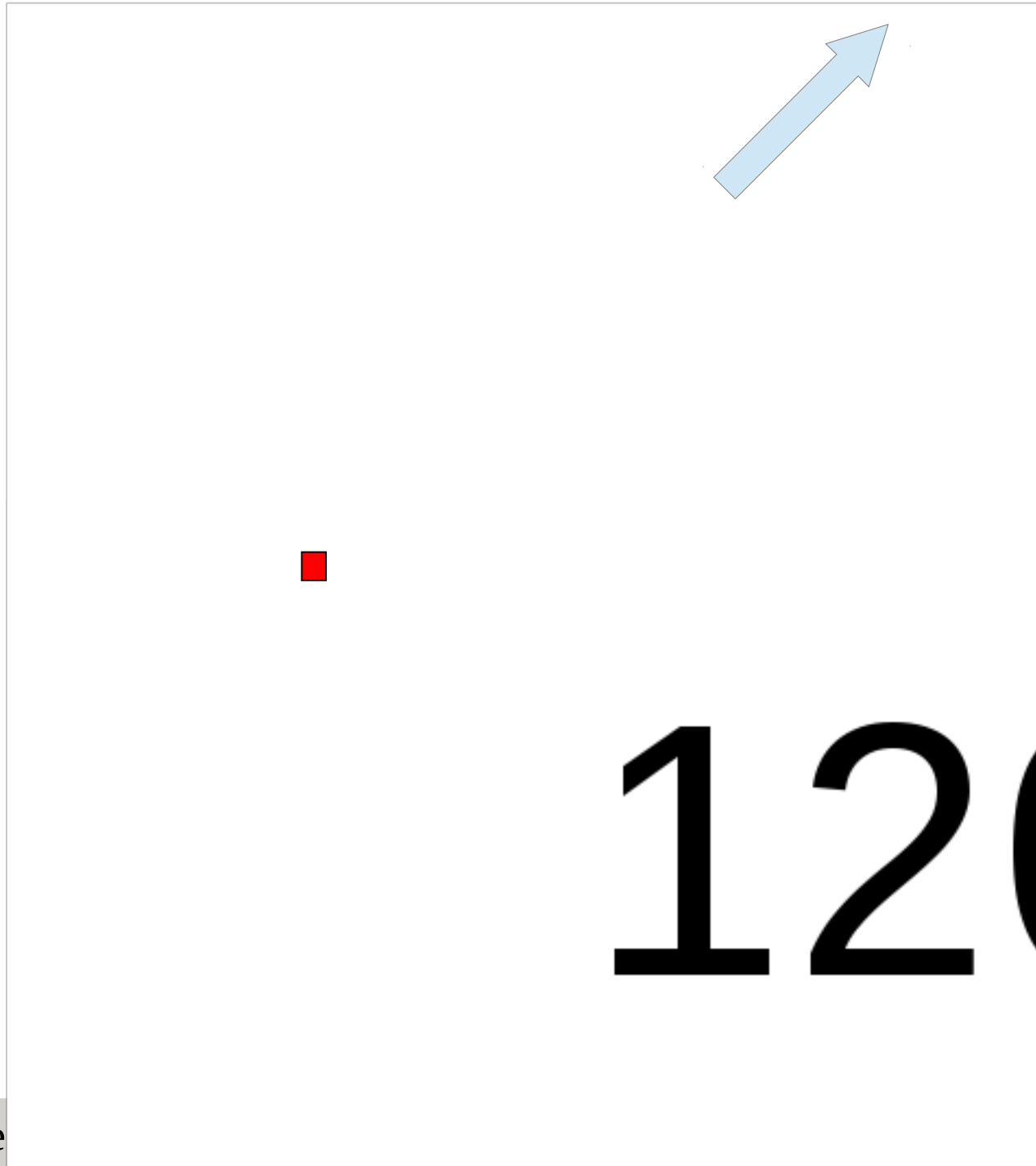
— Line-averaging
laser gas
detector

y
(m)

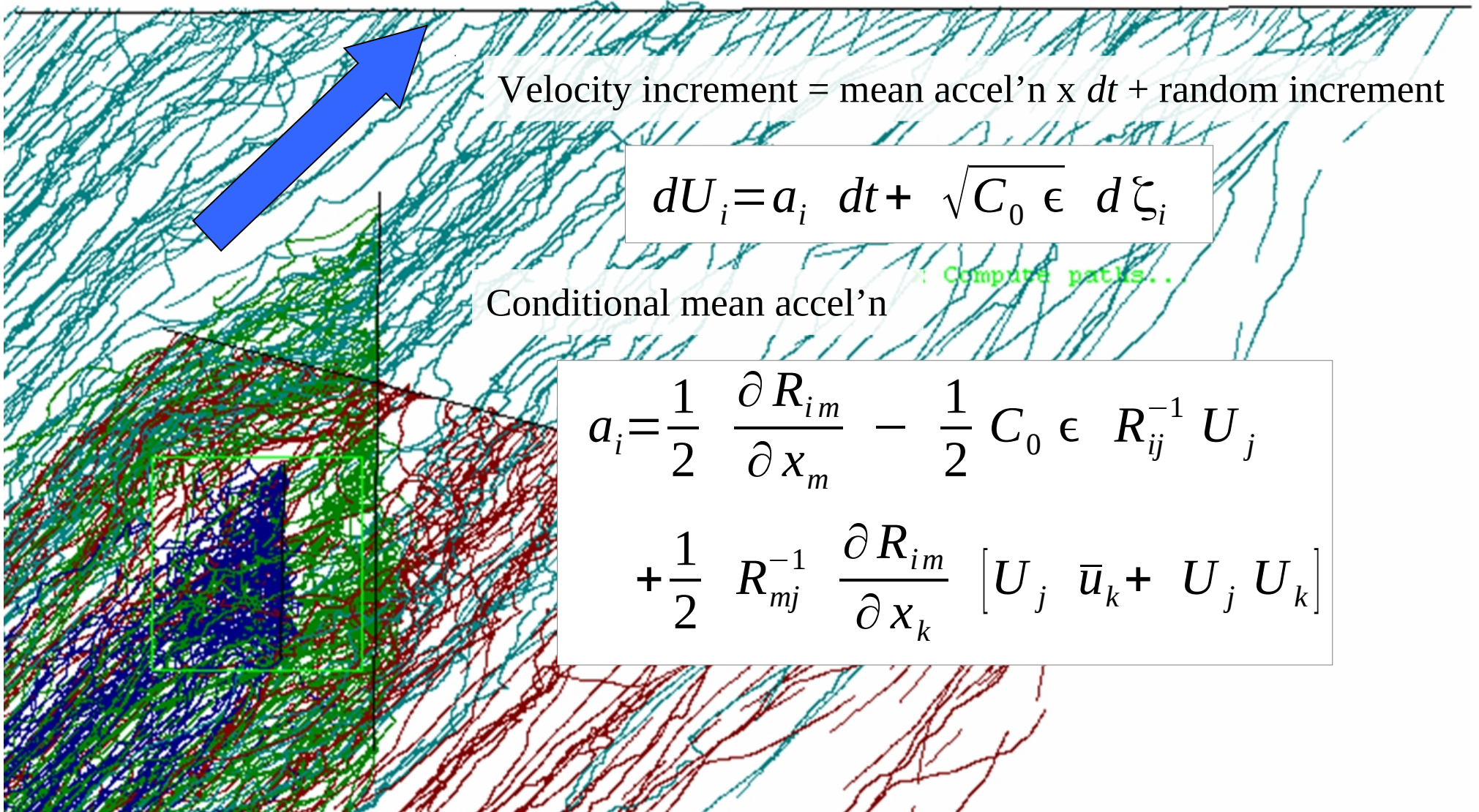
- release rate Q controlled and known

- many trials for each configuration

Configurations of laser methane dete

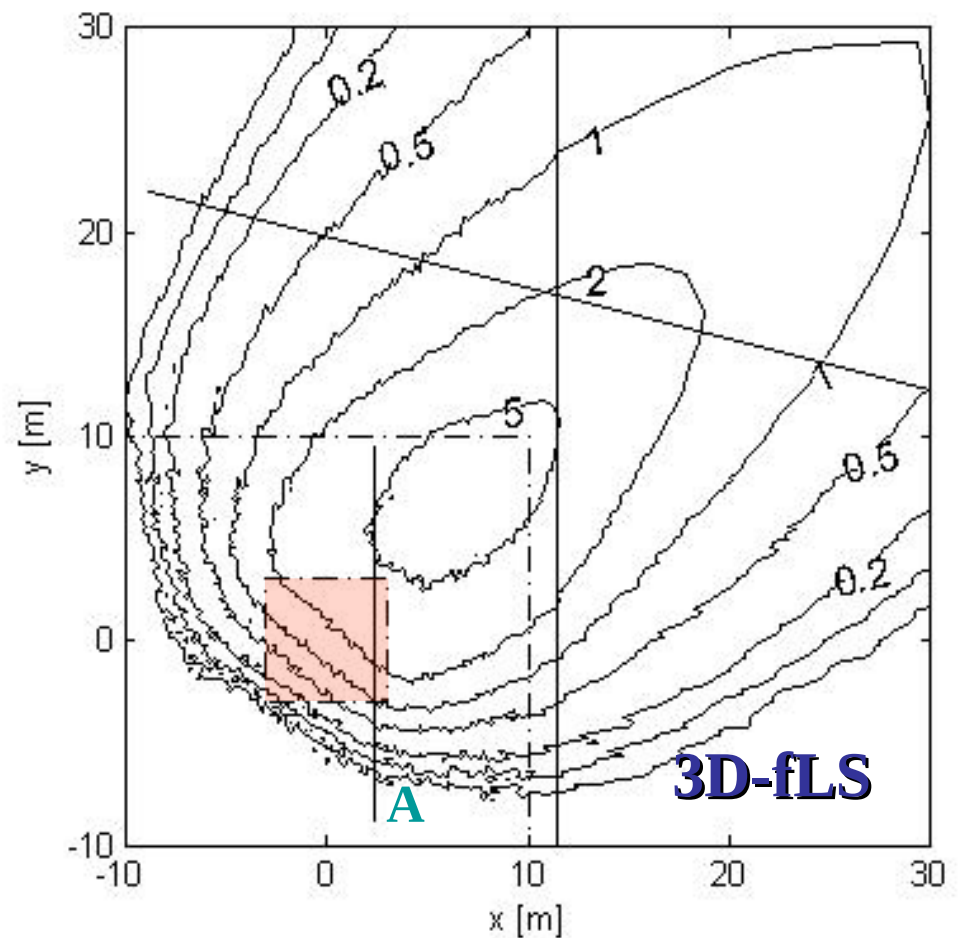
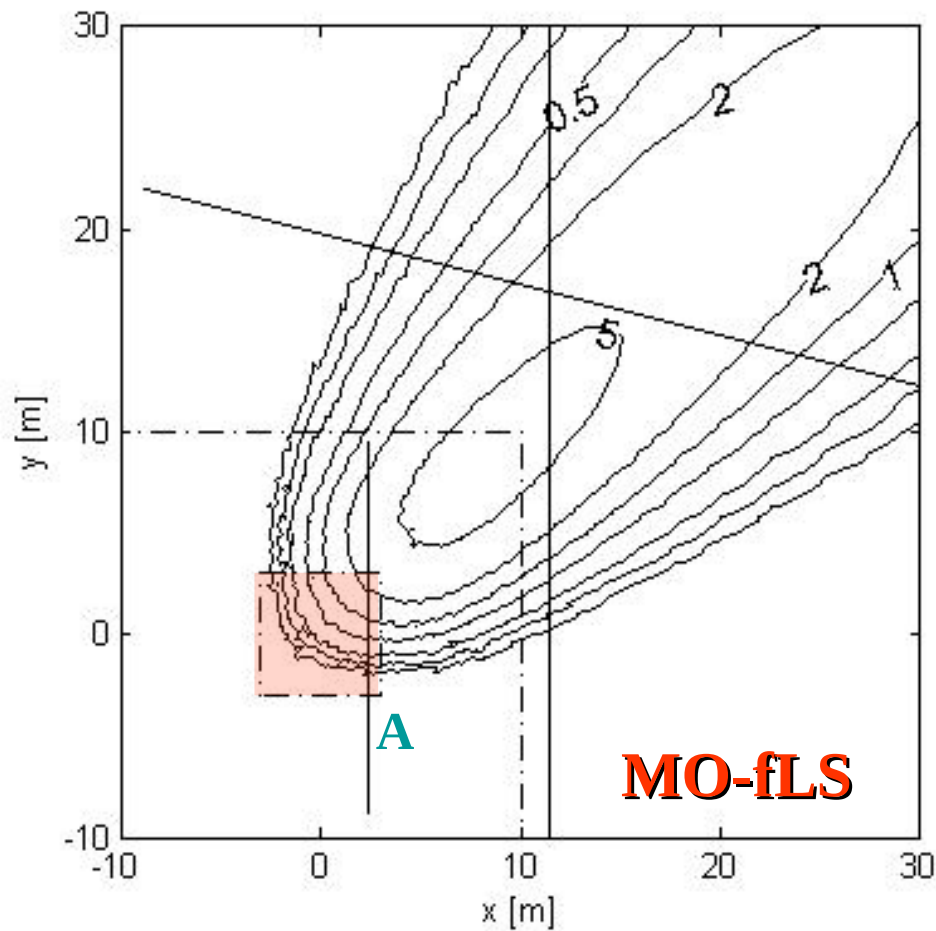


Compute C/Q ratio using 3D-bLS model (driven by computed wind)



- $R_{ij} = \overline{u'_i u'_j}$ the Reynolds stress tensor, provided by Fluent along with \bar{u}_i , ϵ

Computed concentration contours

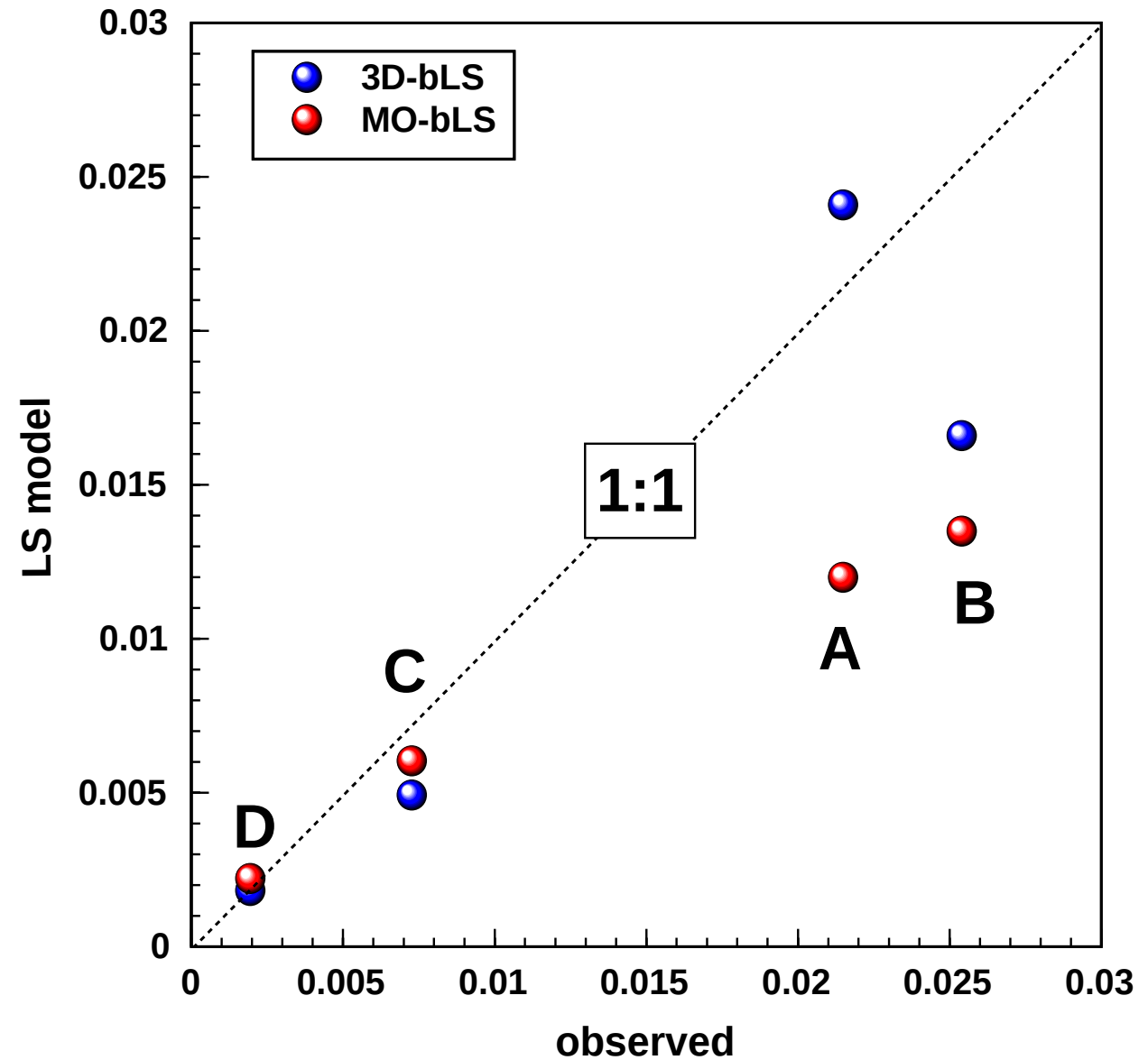
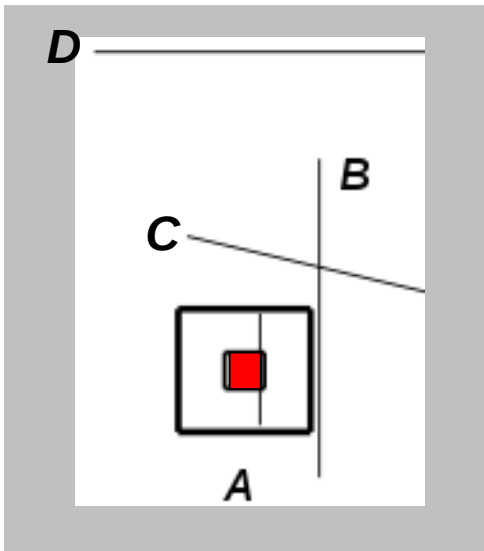


- (100 x) normalized concentration SC/Q at height of lasers
- narrow, elongated plume in (fictitious) undisturbed MO flow
- fatter plume in the “real” flow (or Fluent’s approx. to it)

Performance of inverse dispersion

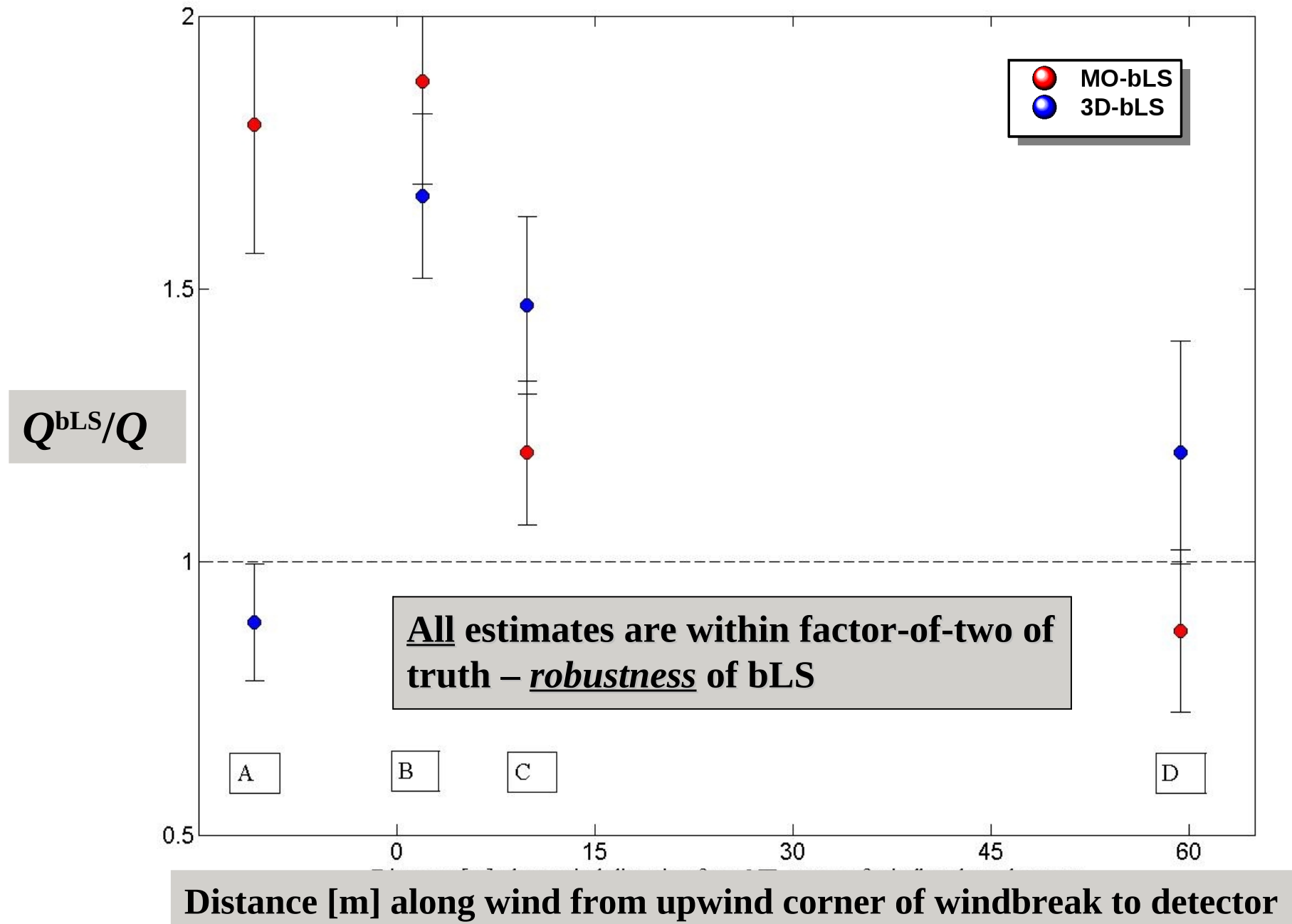
Computed versus measured UC/Q ratio at four laser positions

- A inside shelter
- B just outside
- D most distant



- perfect performance would be 1:1 line

Ratio of inferred to true source strength



Conclusion

- estimates are within factor-of-two both for MO-bLS and 3D-bLS
- basing bLS inverse-dispersion on an approximation to the disturbed wind field (“3D-bLS”) advantageous if detection point is in highly disturbed flow
- however “3D-bLS” very cumbersome relative to “MO-bLS” (which approximates the winds as being undisturbed)
- no advantage of 3D-bLS over MO-bLS if detection point far from source

