Micrometeorological methods to determine methane emissions

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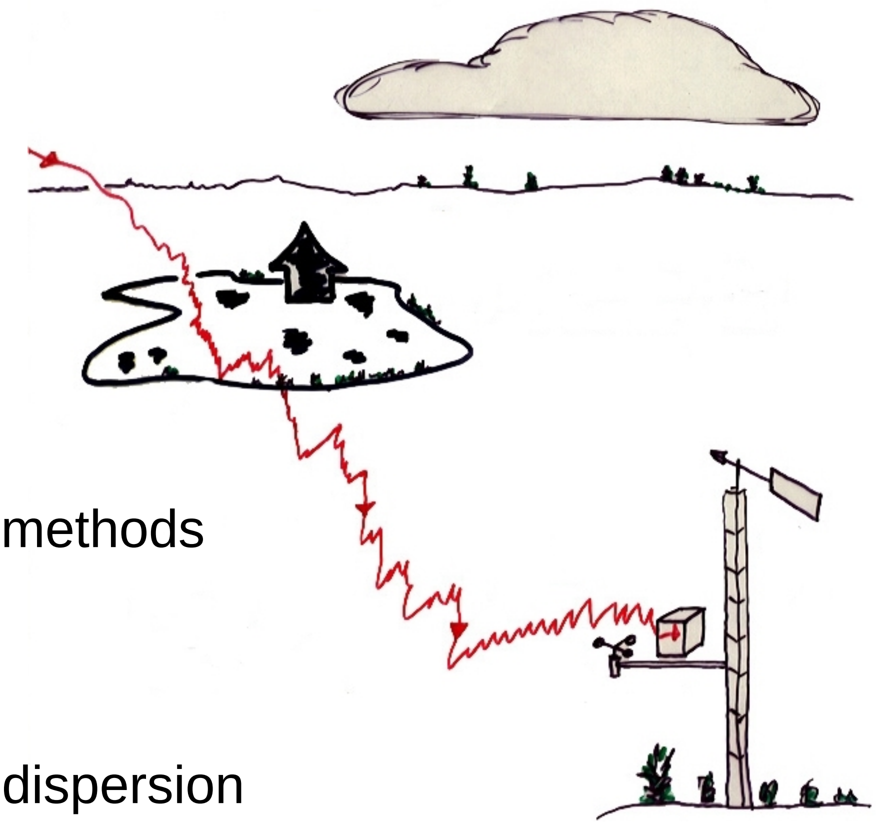


20 min, 17 slides

- survey of micromet methods
- review IHF method
- review bLS inverse dispersion method

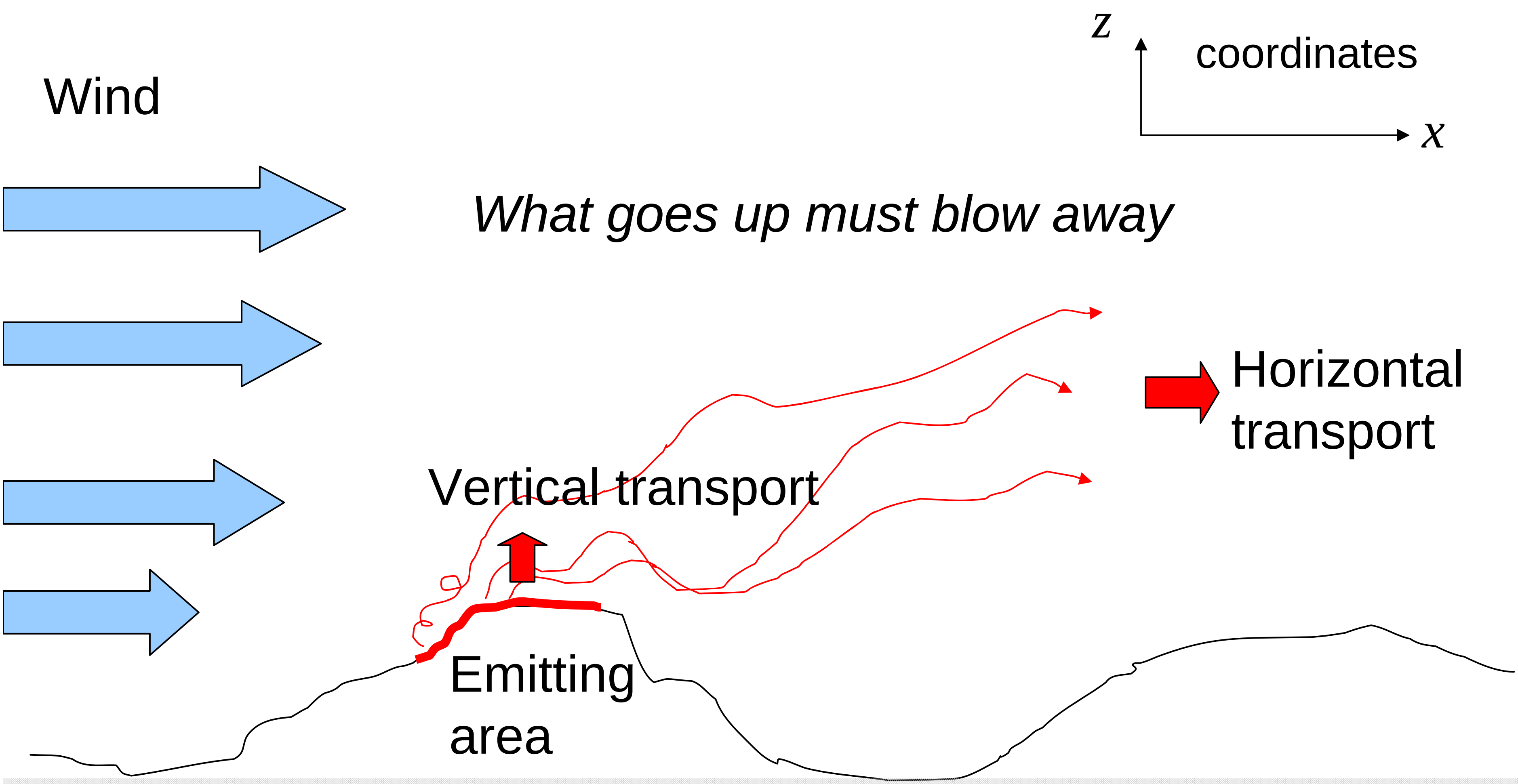
20 min

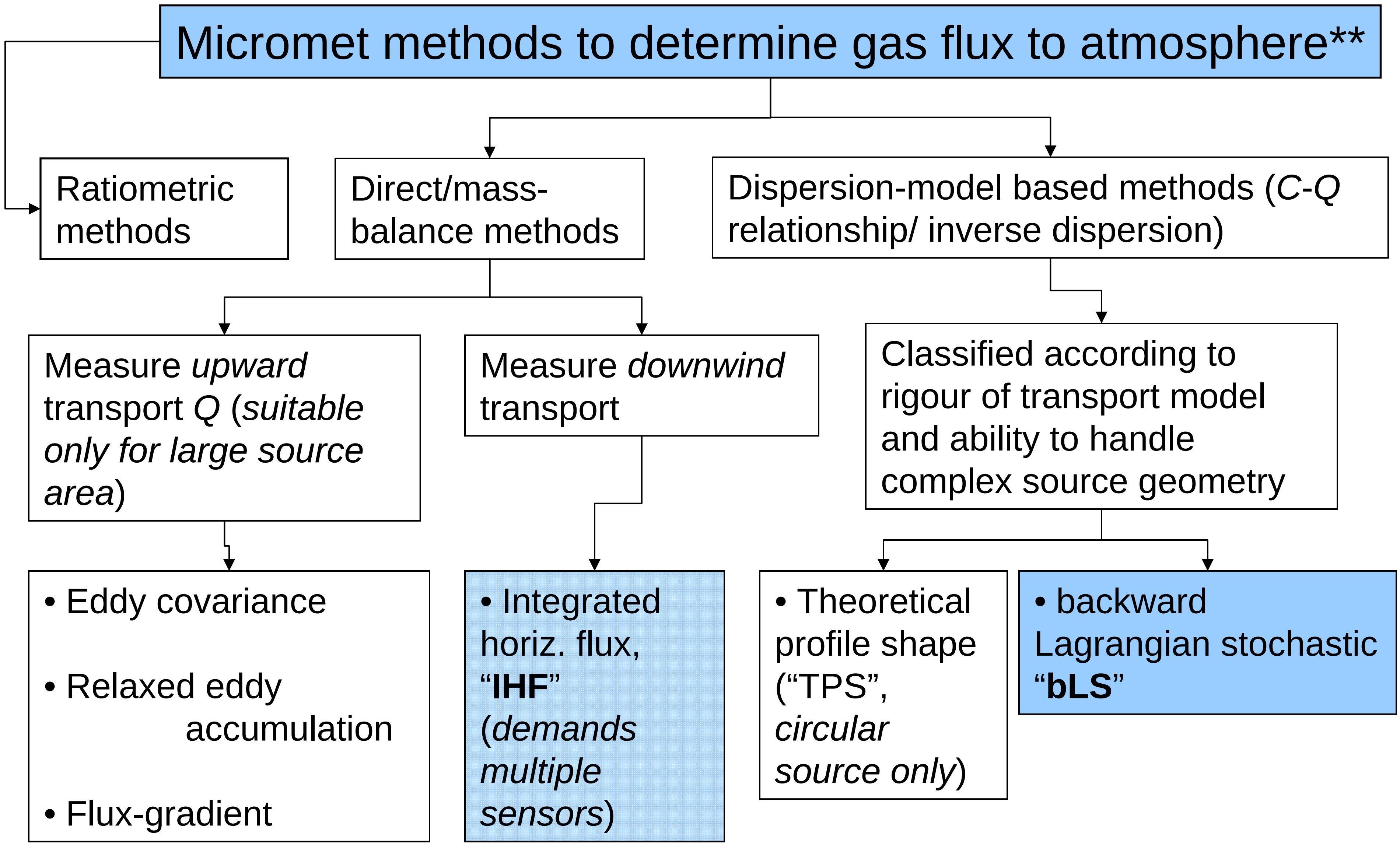
- demonstrate bLS using WindTrax

Banff2010.ppt
J.D. Wilson, presented at GGAA Banff, Oct. 2010
(Comments added subsequently for posting to web site)

Micro-meteorological methods estimate gas entering the atmosphere (as opposed to observing what goes missing from the substrate).

- Because they fluctuate, winds and gas transfer rates necessarily must be averages, over a period of something like 15 – 60 min.



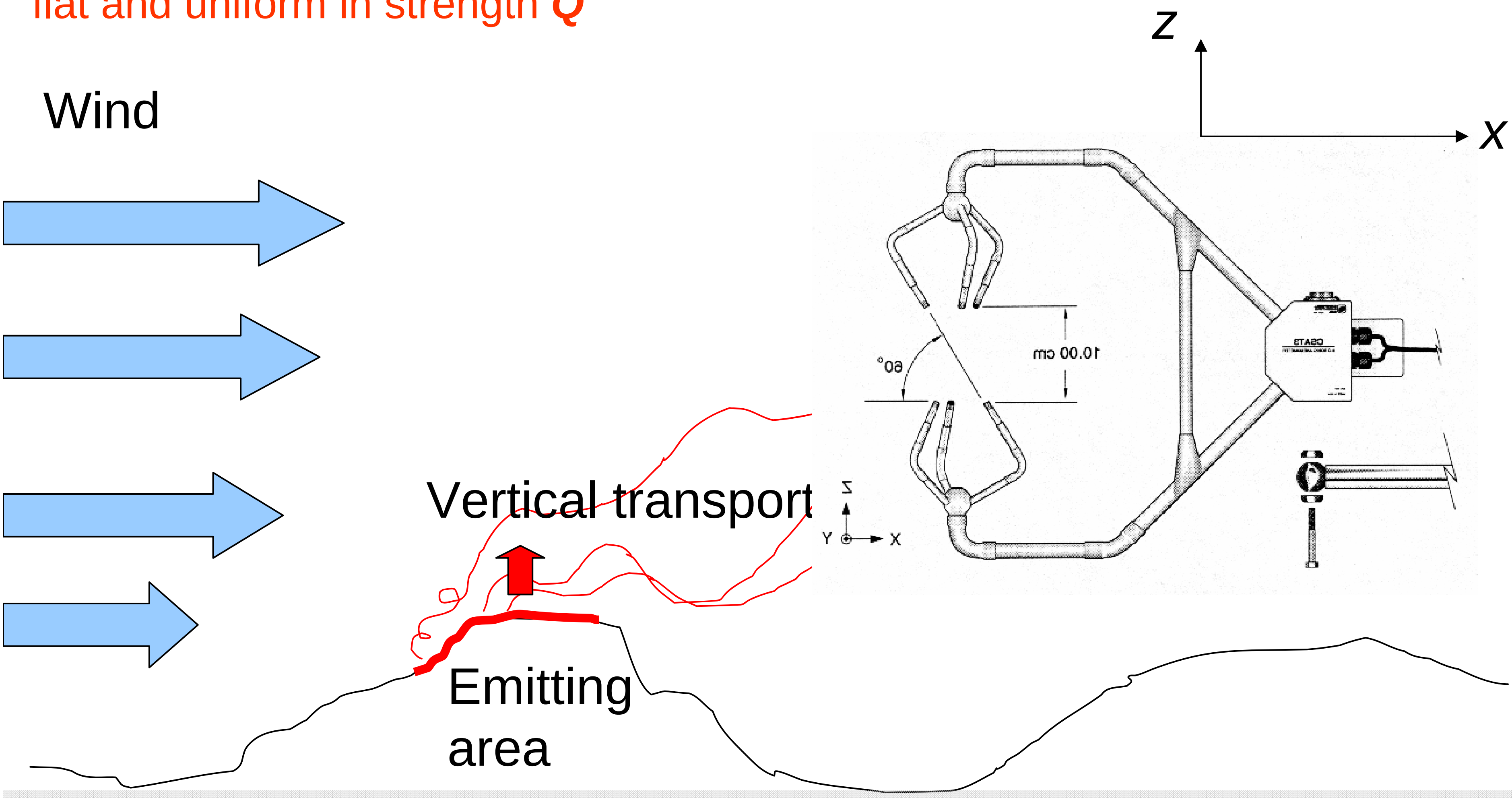


***Classification is arbitrary; not all variants of main methods are indicated*

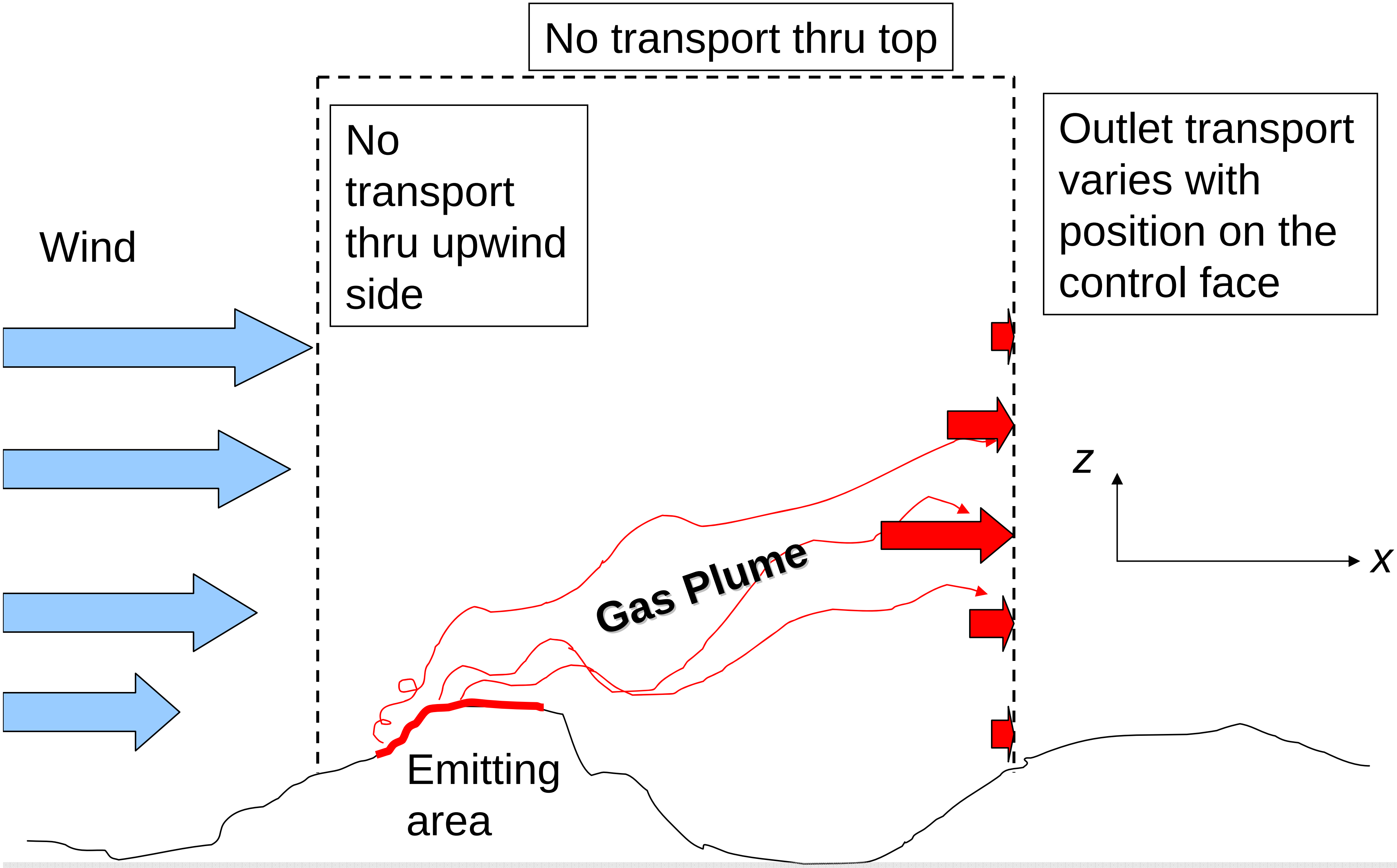
• will concentrate on IHF & bLS

May focus on measuring the vertical transport (e.g. by eddy covariance) or on measuring the horizontal transport

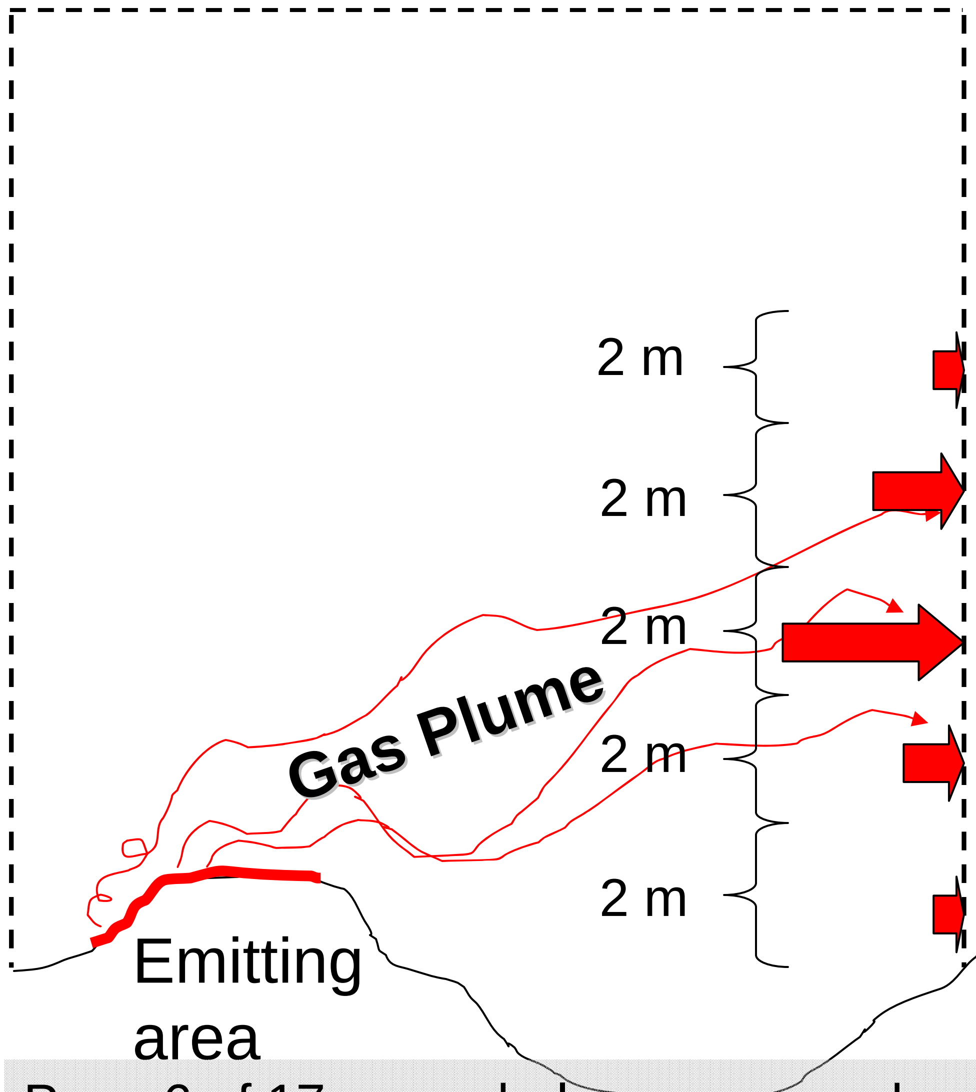
- quantifying the vertical transport rate problematic unless symmetry prevails: require uniformity of wind and of the source – in effect source must be large, flat and uniform in strength ***Q***



Mass balance (IHF) approach – illustrated in two dimensions



Mass balance approach demands summation of the outlet transport, because the latter varies with position on the control face



- large number of windspeed (*U*) and concentration (*C*) sensors required

$1\ mg\ m^{-2}\ s^{-1} \times 2\ m = 2\ mg\ m^{-1}\ s^{-1}$

$5\ mg\ m^{-2}\ s^{-1} \times 2\ m = 10\ mg\ m^{-1}\ s^{-1}$

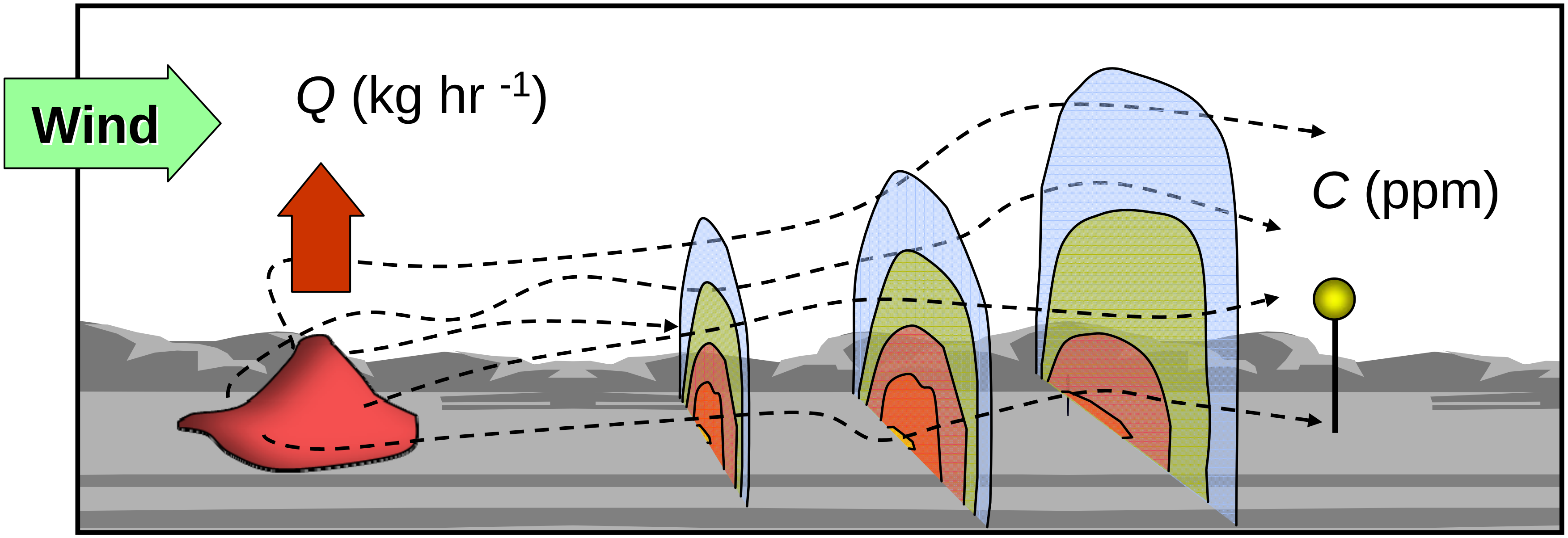
$10\ mg\ m^{-2}\ s^{-1} \times 2\ m = 20\ mg\ m^{-1}\ s^{-1}$

$3\ mg\ m^{-2}\ s^{-1} \times 2\ m = 6\ mg\ m^{-1}\ s^{-1}$

$1\ mg\ m^{-2}\ s^{-1} \times 2\ m = 2\ mg\ m^{-1}\ s^{-1}$

SUM = **Q** = $40\ mg\ m^{-1}\ s^{-1}$

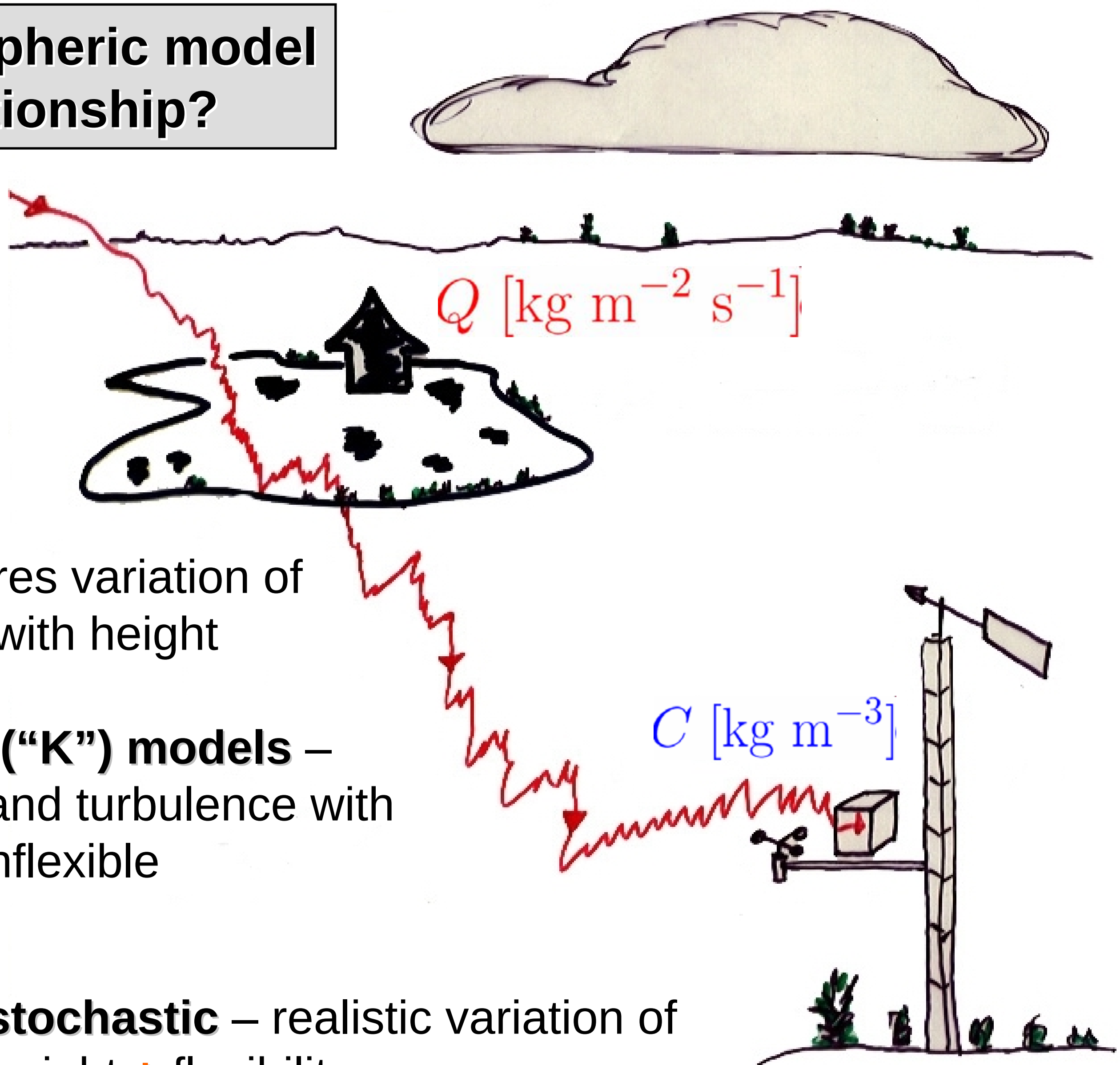
Inverse Dispersion method to deduce Gas Emissions



- Atmospheric dispersion model relates downwind concentration ***C*** to emission rate ***Q*** for prevailing regime of wind & turbulence
- Measurement of ***C*** (minus background) + model permits to infer ***Q***

+ simple, remote measurement + unrestricted source geometry
+ no disruption of operations

Fidelity of the atmospheric model providing *C-Q* relationship?

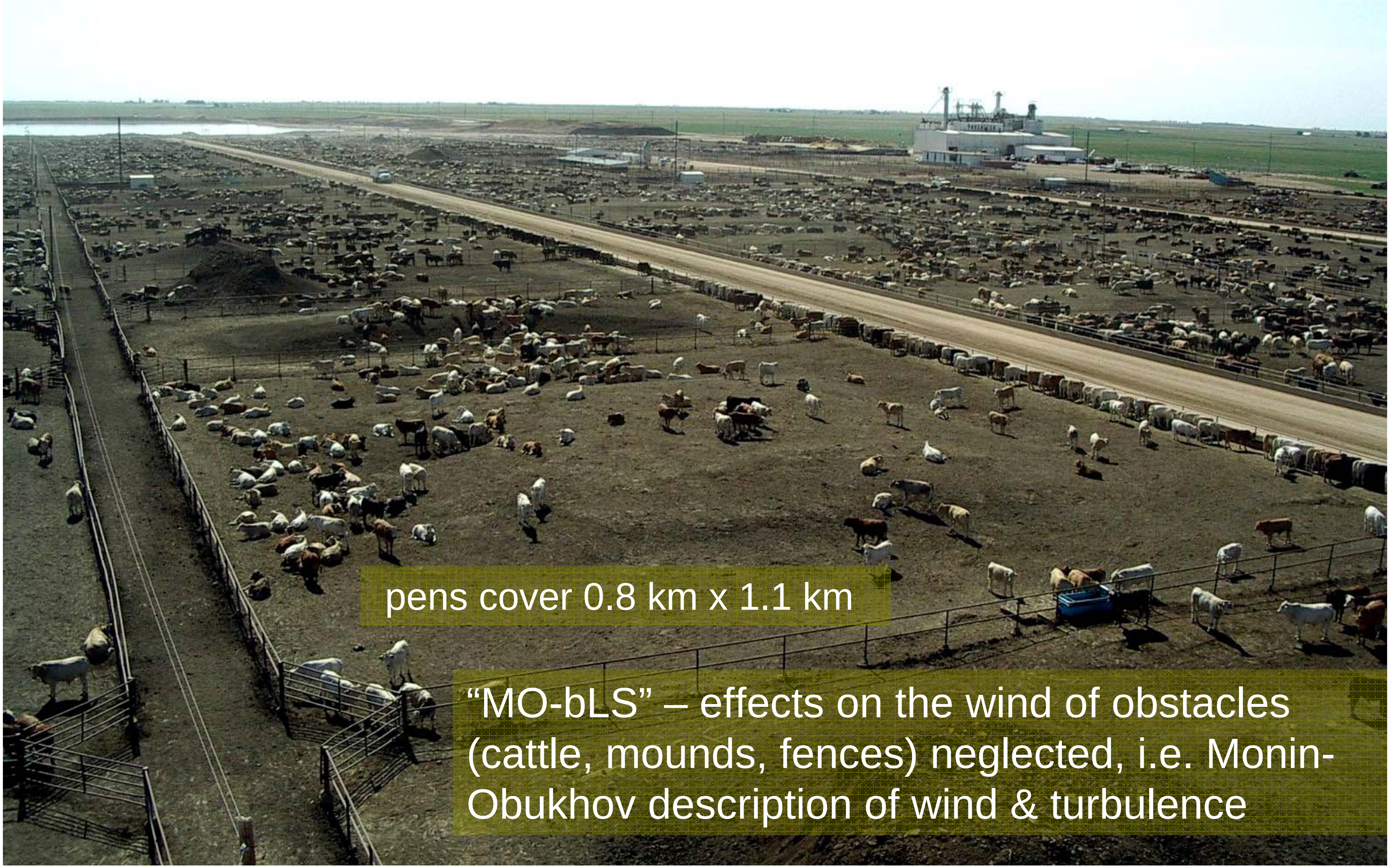


- **Gaussian plume** – ignores variation of wind speed and direction with height

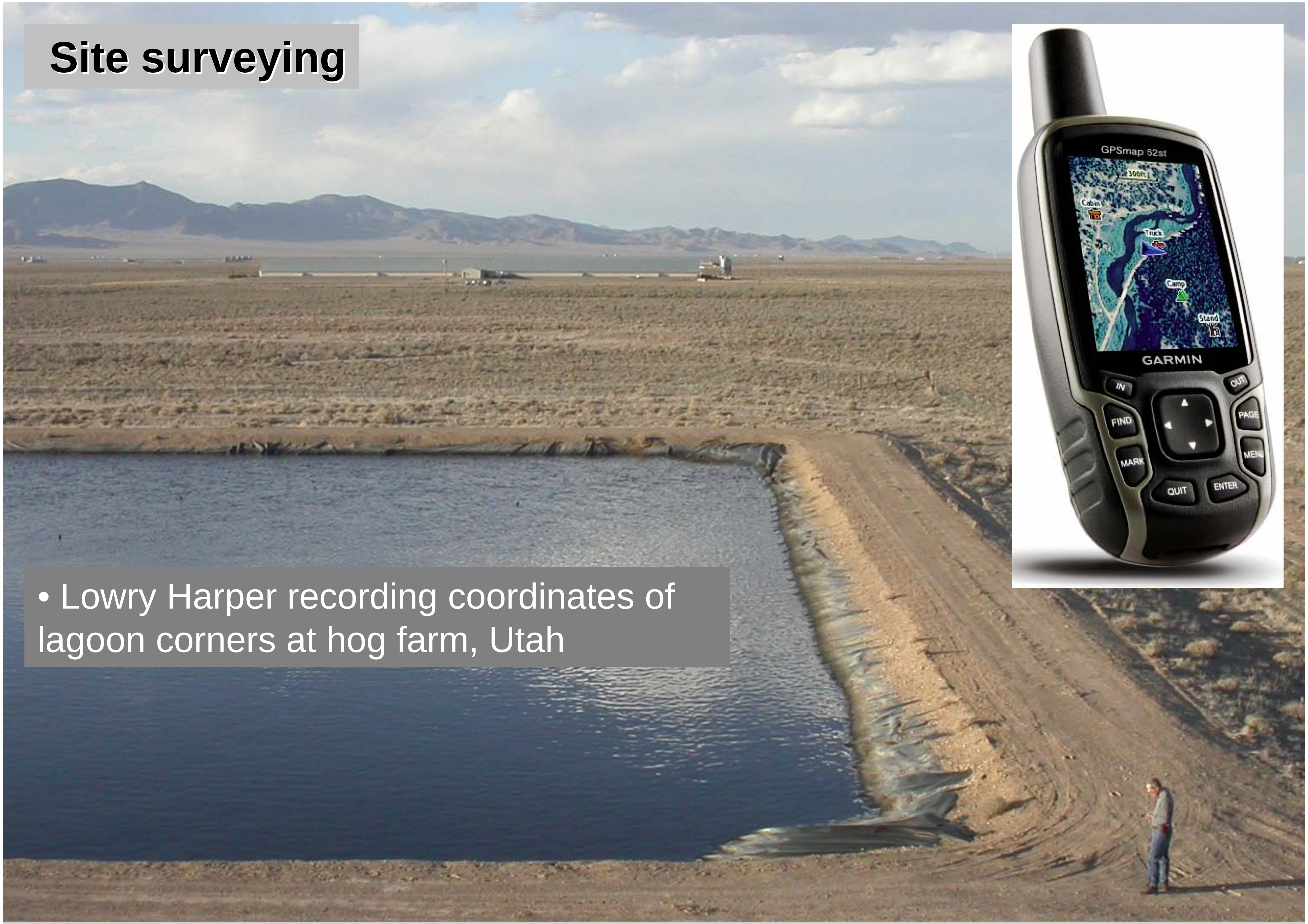
- **other "eddy diffusion" ("K") models** – realistic variation of wind and turbulence with height, but cumbersome/inflexible

- **backward Lagrangian stochastic** – realistic variation of wind and turbulence with height **+** flexibility

Feedlot Emissions (Texas, spring 2005; 40, 000 cattle)

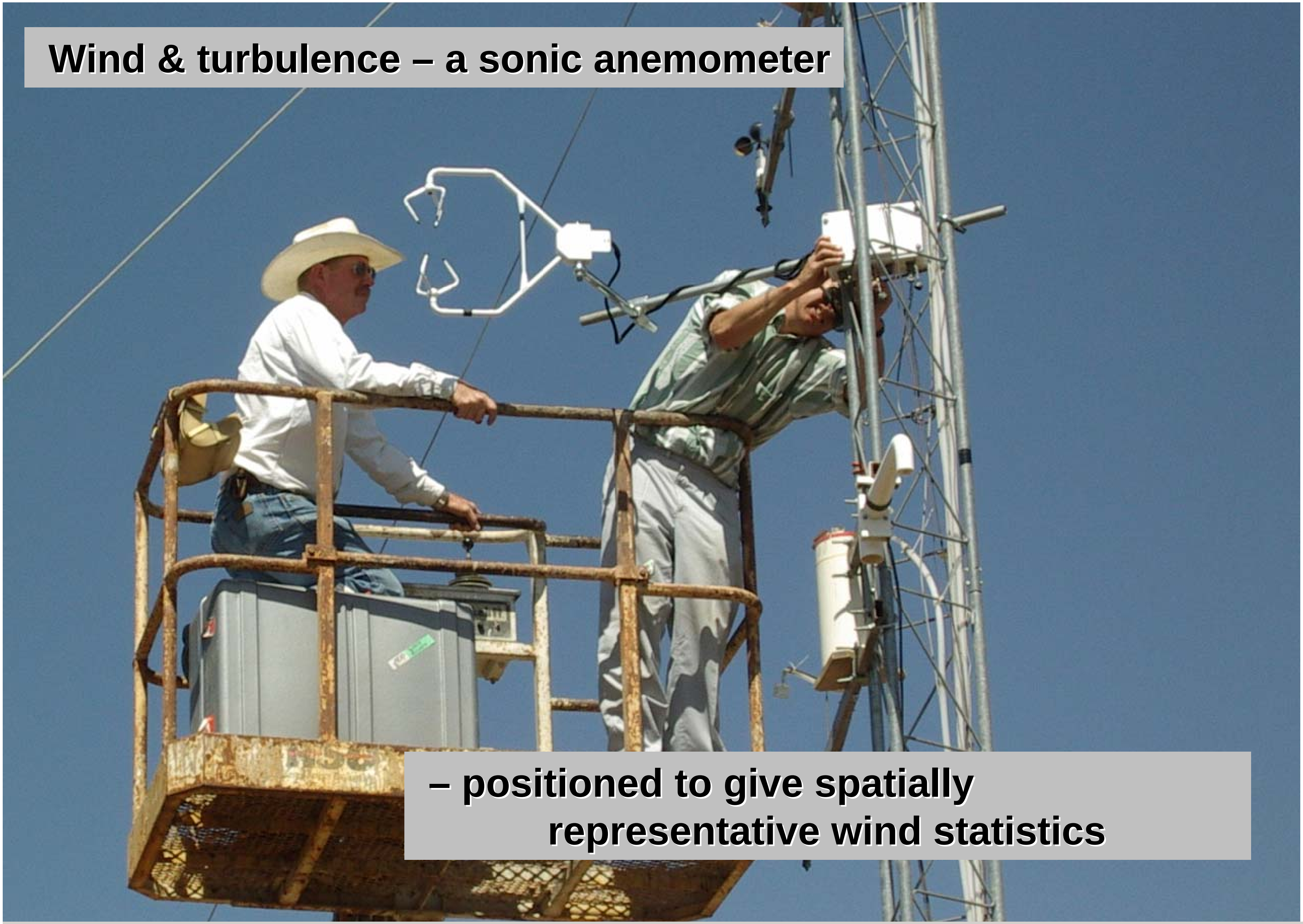


Site surveying



- Lowry Harper recording coordinates of lagoon corners at hog farm, Utah

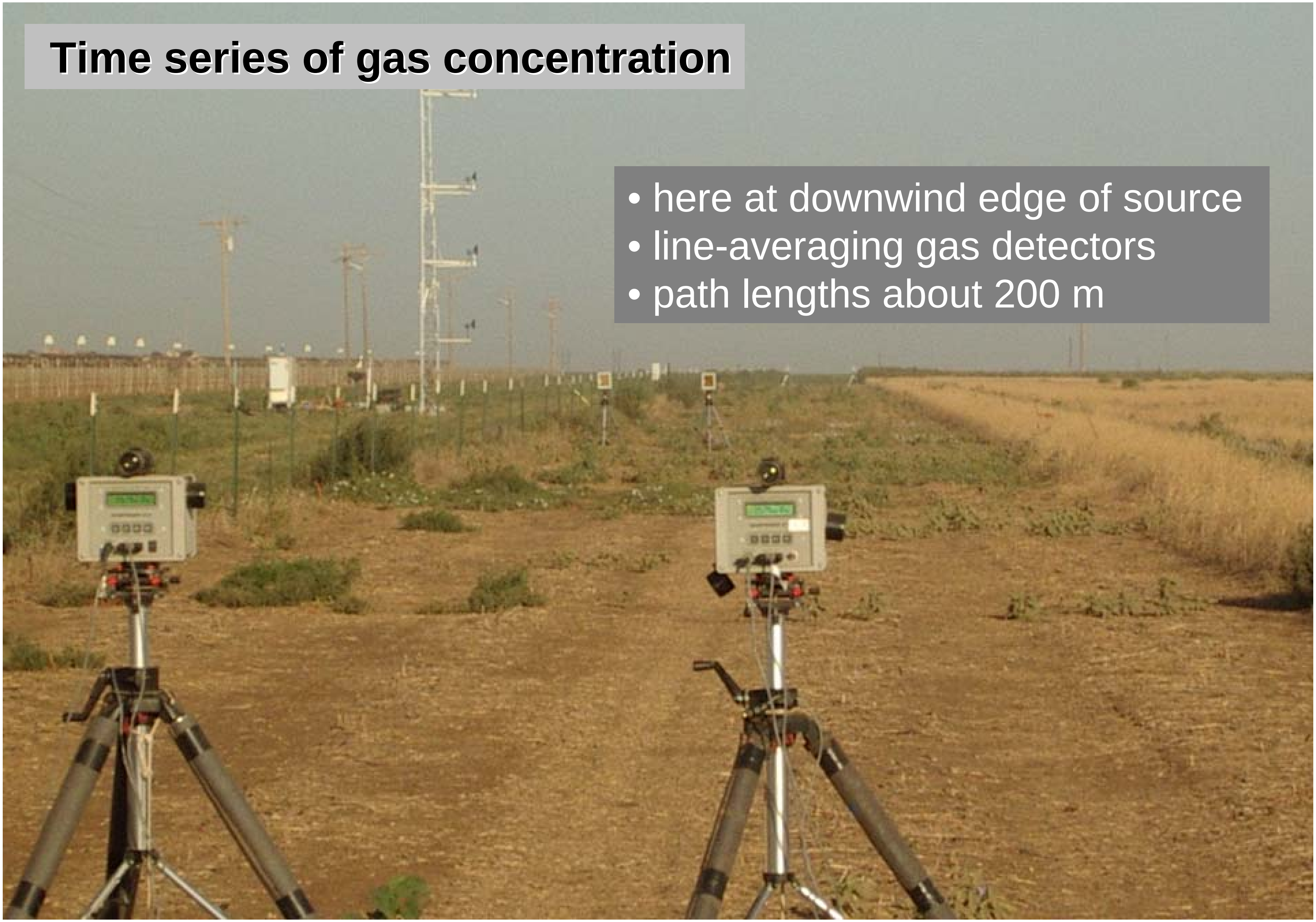
Wind & turbulence – a sonic anemometer



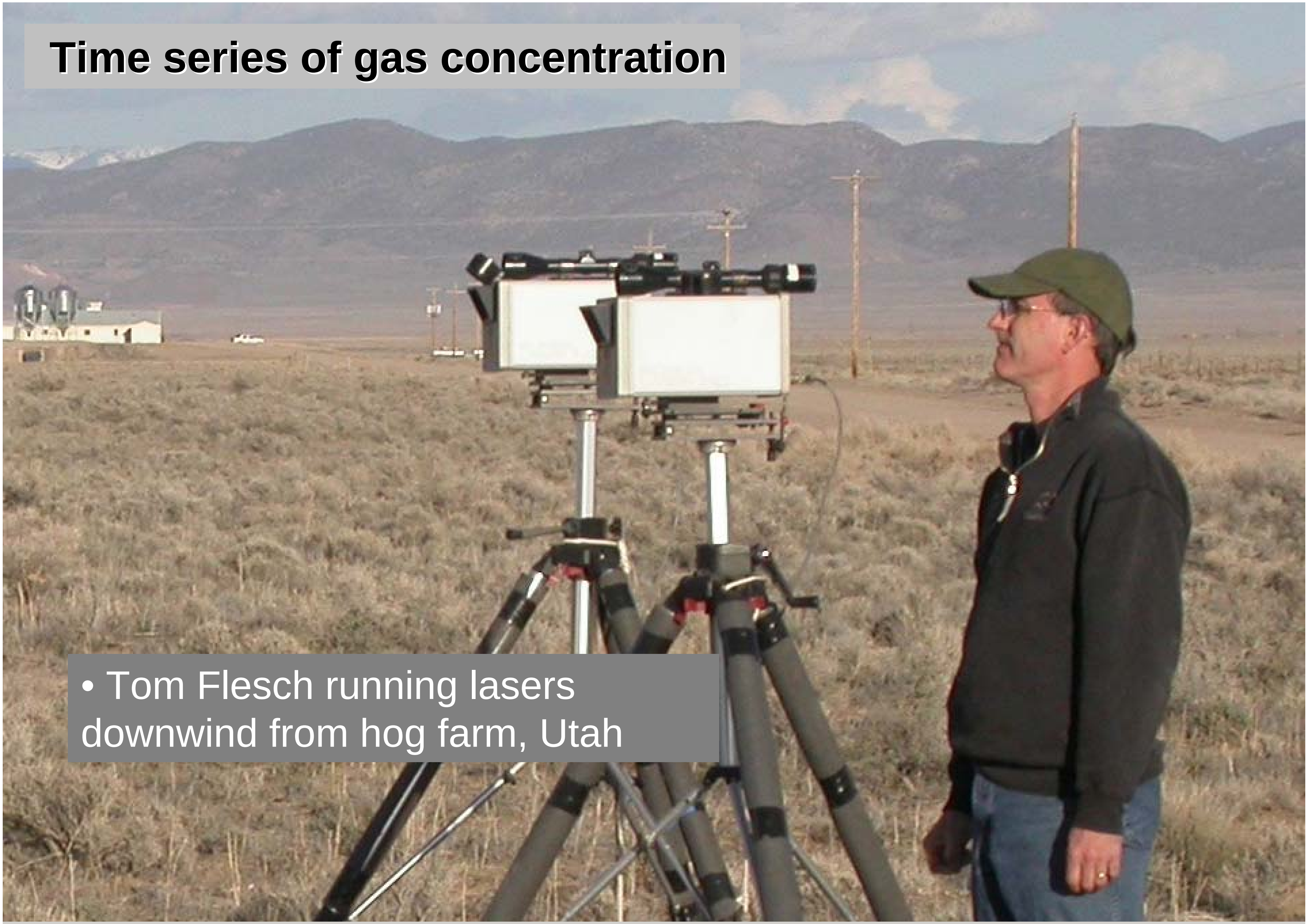
– positioned to give spatially representative wind statistics

Time series of gas concentration

- here at downwind edge of source
- line-averaging gas detectors
- path lengths about 200 m

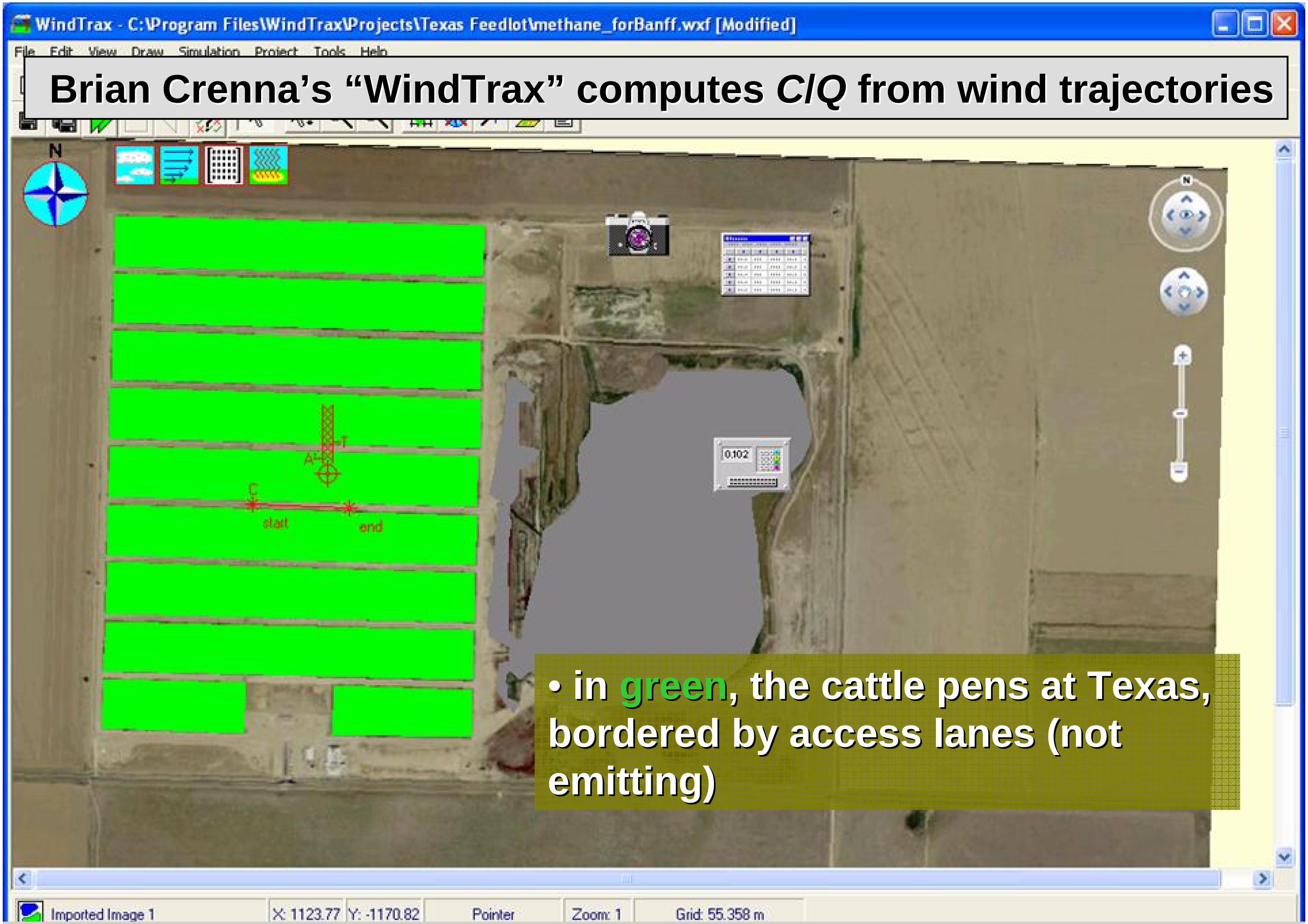


Time series of gas concentration



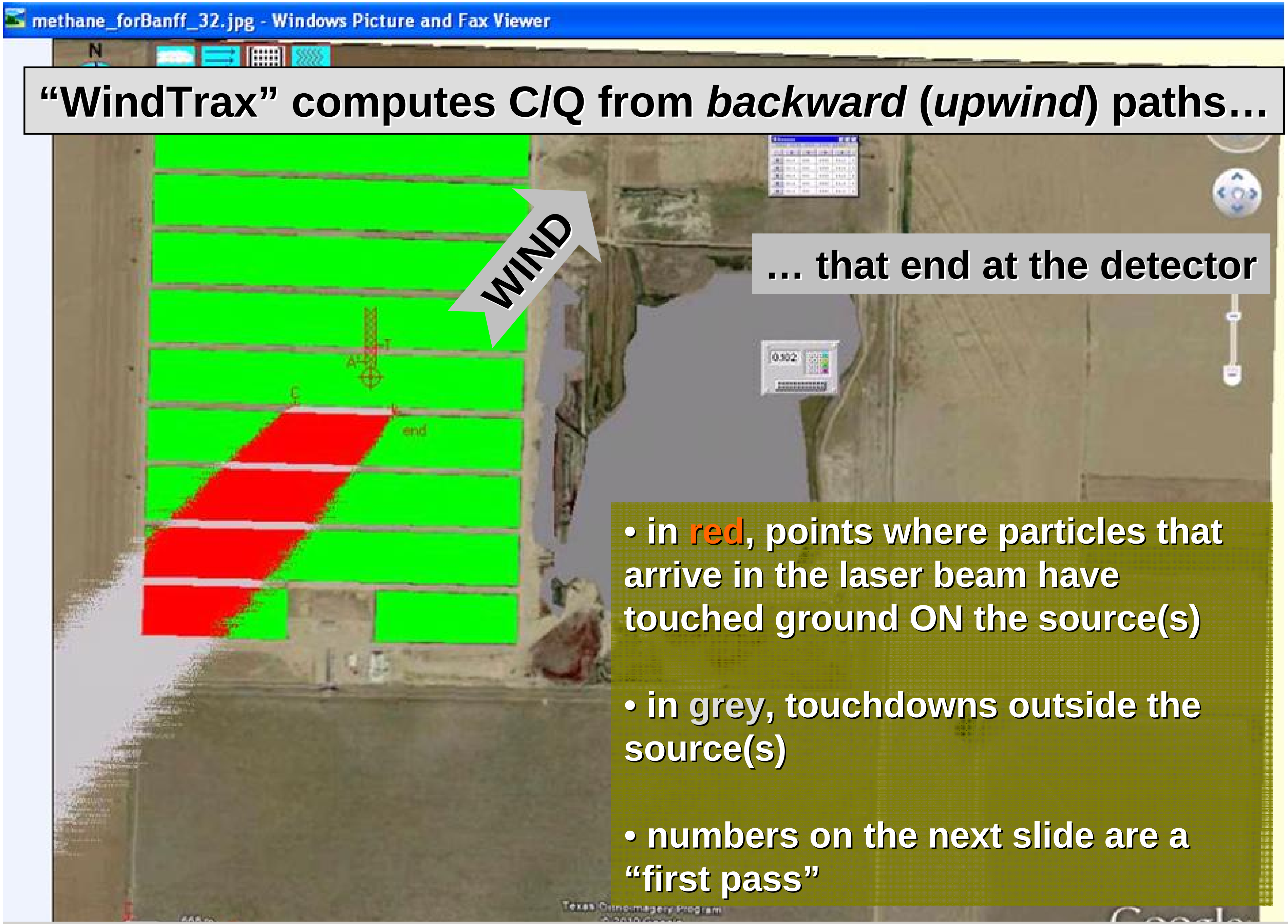
- Tom Flesch running lasers downwind from hog farm, Utah

Brian Crenna's "WindTrax" computes *C/Q* from wind trajectories



- in green, the cattle pens at Texas, bordered by access lanes (not emitting)

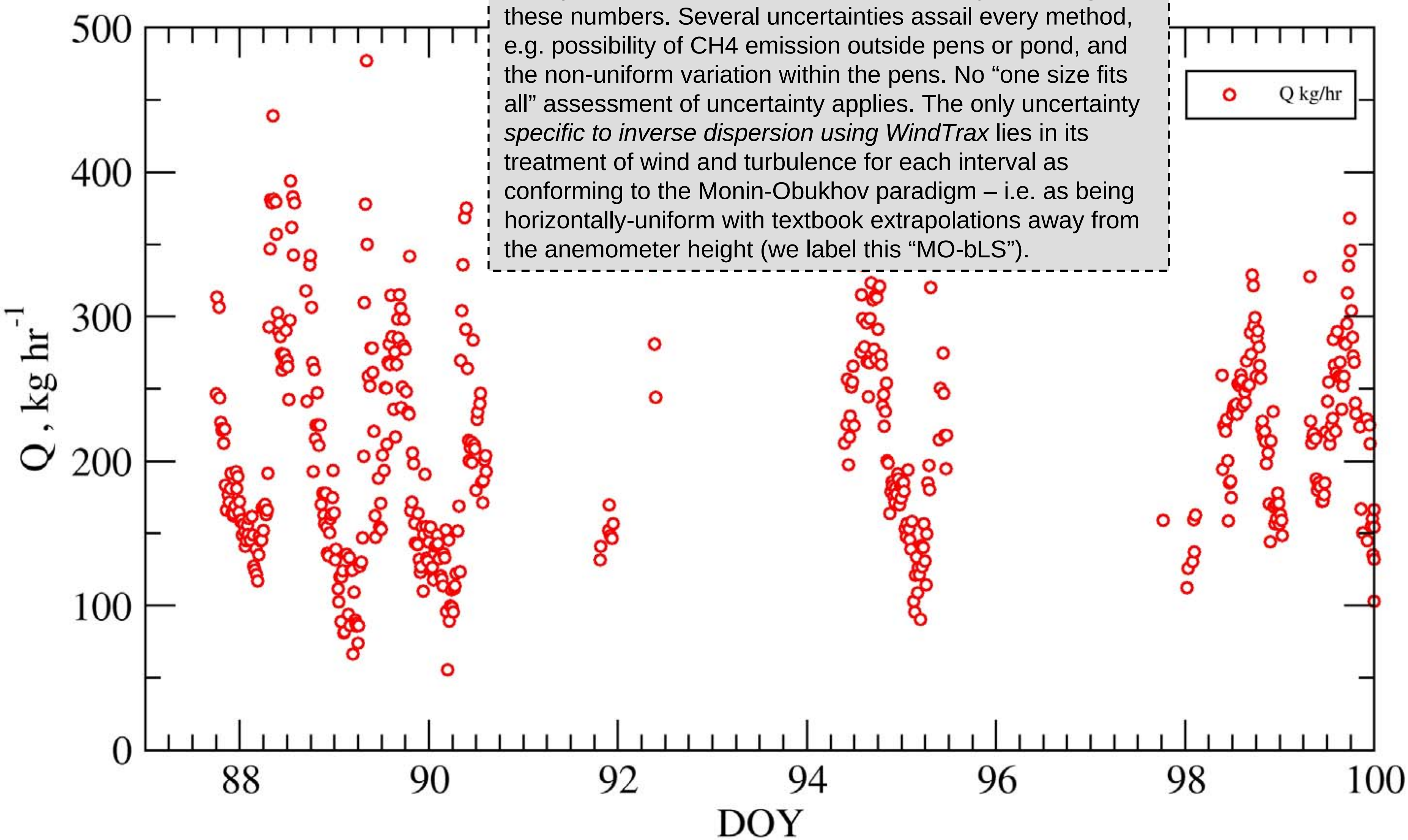
"WindTrax" computes C/Q from *backward* (*upwind*) paths…



… that end at the detector

- in red, points where particles that arrive in the laser beam have touched ground ON the source(s)
- in grey, touchdowns outside the source(s)
- numbers on the next slide are a "first pass"

Methane flux, Texas feedlot (40,000 head)



The question was raised as to the *uncertainty* attending these numbers. Several uncertainties assail every method, e.g. possibility of CH4 emission outside pens or pond, and the non-uniform variation within the pens. No "one size fits all" assessment of uncertainty applies. The only uncertainty *specific to inverse dispersion using WindTrax* lies in its treatment of wind and turbulence for each interval as conforming to the Monin-Obukhov paradigm – i.e. as being horizontally-uniform with textbook extrapolations away from the anemometer height (we label this "MO-bLS").

bLS method for inferring emission rate from measured concentration

• convenient; provides a time-resolved (but typically non-continuous) record with overall accuracy that (past experience suggests) converges to about +/- 10% to 20% when individual 15-min estimates are pooled (see relevant publications concerning cases where emission rate is independently known)

• experience so far suggests bLS is rather robust against deviation of setup from the ideal (Wilson et al. 2010, J. Appl. Meteorol. Climatol. **49**). *Even if wind is highly disturbed and concentration detector is near the obstacles, Q unlikely to be wrong by factor as large as 2.*

• requires

- well defined background C^{bk} – or use two detectors & treat C^{bk} as unknown
- that source area(s) can be delineated from non-source
- detector placed close enough that concentration rise is resolved, yet in a configuration such that trajectories to the detector are in undisturbed wind