NCAR

AUTOMATED SOURCE PARAMETER AND LOW LEVEL WIN ESTIMATION FOR ATMOSPHERIC TRANSPORT AND DISPERSION APPLICATIONS

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STE recent developments

- All source parameters: $[q_s, x_s, y_s, z_s, t_r]$ and wind $[u_e, v_e]$ are adjusted during the estimation process.
- Either wind components or wind speed and direction can be used and adjusted.
- Two step minimization:
  - 1) *$[x_s, y_s, z_s, t_r, u_e, v_e]$ with logarithmic concentration*
  - *2) q_s with plain concentration*
- Addition of a background term (a priori information) in the cost function to remove ambiguities between source parameters.

Gaussian Puff Model

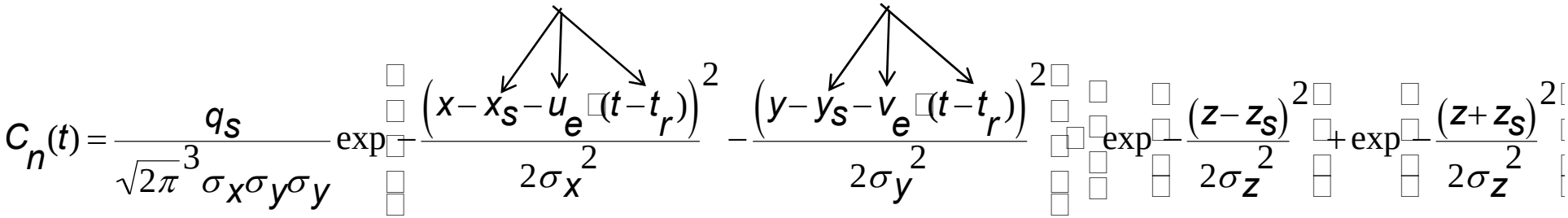
Input vector: $S = \begin{bmatrix} q_s \\ x_s \\ y_s \\ z_s \\ t_r \\ u_e \\ v_e \end{bmatrix}$ **Output vector:** $C(t) = \begin{bmatrix} c_1(t) \\ c_2(t) \\ \dots \\ c_N(t) \end{bmatrix}$

Model at time *t* on a given grid *1 ≤ n ≤ N:*

$$C_n(t) = \frac{q_s}{\sqrt{2\pi}^3 \sigma_x \sigma_y \sigma_y} \exp\left[-\frac{(x - x_s - u_e(t - t_r))^2}{2\sigma_x^2} - \frac{(y - y_s - v_e(t - t_r))^2}{2\sigma_y^2}\right] \left[\exp\left(-\frac{(z - z_s)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z + z_s)^2}{2\sigma_z^2}\right)\right]$$

Ambiguity location wind

Same concentrations can be obtained by permutations of source location, wind and release time



$$C_n(t) = \frac{q_s}{\sqrt{2\pi}^3 \sigma_x \sigma_y \sigma_y} \exp\left[-\frac{\left(x - x_s - u_e (t - t_r)\right)^2}{2\sigma_x^2} - \frac{\left(y - y_s - v_e (t - t_r)\right)^2}{2\sigma_y^2} \right] \left[\exp -\frac{(z - z_s)^2}{2\sigma_z^2} + \exp -\frac{(z + z_s)^2}{2\sigma_z^2} \right]$$

Prior information needs to be provided to remove the ambiguity

Cost function with prior (background) information

Distance of model predicted concentration C to the sensor measurements C^{obs} (with uncertainty σ^{obs})

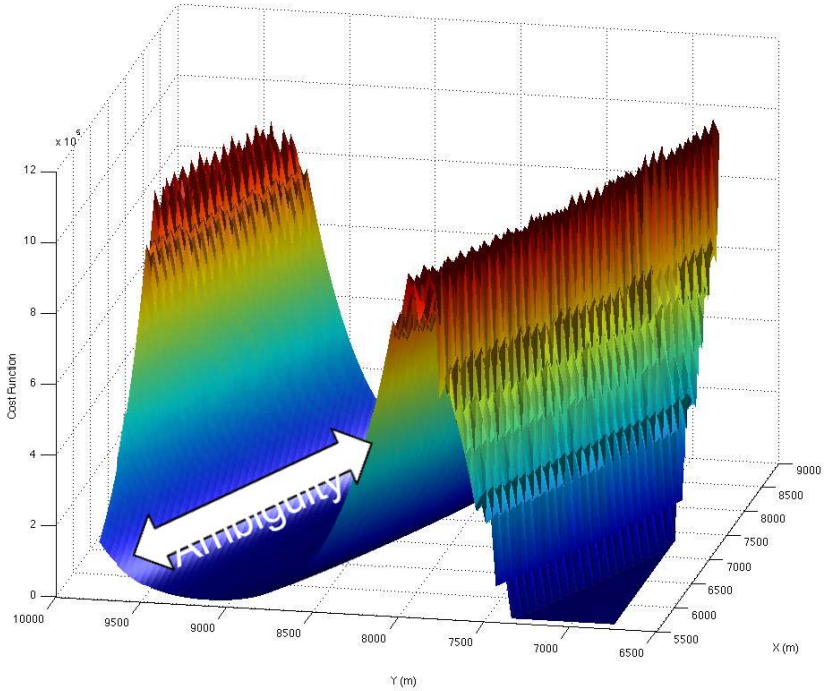
$$J^{obs} = \frac{1}{2}\left[\frac{C^{obs}(t) - C(t)}{\sigma^{obs}}\right]^2$$

Distance (ound term:

$$J^{bck} = \frac{1}{2}\left[\frac{x_s^{bck} - x_s}{\sigma^{x}}\right]^2 + \left(\right.$$

$$\frac{1}{2}\left[\frac{v_e^{bck} - v_e}{\sigma^{v}}\right]^2$$

Total cost



Important point

σ's are weight between the background information (first guess source provided by reverse SCIPUFF) and the concentration from sensor

$$2J = \left(\frac{q_s^{bck} - q_s}{\sigma^q}\right)^2 + \left(\frac{x_s^{bck} - x_s}{\sigma^x}\right)^2 + \left(\frac{y_s^{bck} - y_s}{\sigma^y}\right)^2 + \left(\frac{z_s^{bck} - z_s}{\sigma^z}\right)^2 + \left(\frac{t_r^{bck} - t_r}{\sigma^r}\right)^2 + \left(\frac{u_e^{bck} - u_e}{\sigma^u}\right)^2 + \left(\frac{v_e^{bck} - v_e}{\sigma^v}\right)^2 + \left(\frac{C^{obs}(t) - C(t)}{\sigma^{obs}}\right)^2$$

$$2J = \left(\frac{q_s^{bck} - q_s}{1kg/s}\right)^2 + \left(\frac{x_s^{bck} - x_s}{500m}\right)^2 + \left(\frac{y_s^{bck} - y_s}{500m}\right)^2 + \left(\frac{z_s^{bck} - z_s}{0.5m}\right)^2 + \left(\frac{t_r^{bck} - t_r}{45s}\right)^2 + \left(\frac{u_e^{bck} - u_e}{1.4m/s}\right)^2 + \left(\frac{v_e^{bck} - v_e}{1.4m/s}\right)^2 + \left(\frac{C^{obs}(t) - C(t)}{0.5\left|C_{\max}^{obs} - C_{\min}^{obs}\right|}\right)^2$$

small error, ie high confidence, z_s will be slightly changed during the estimation

It's important that each term is properly scaled, or the corresponding parameter will have too much or too little effect on the minimization.

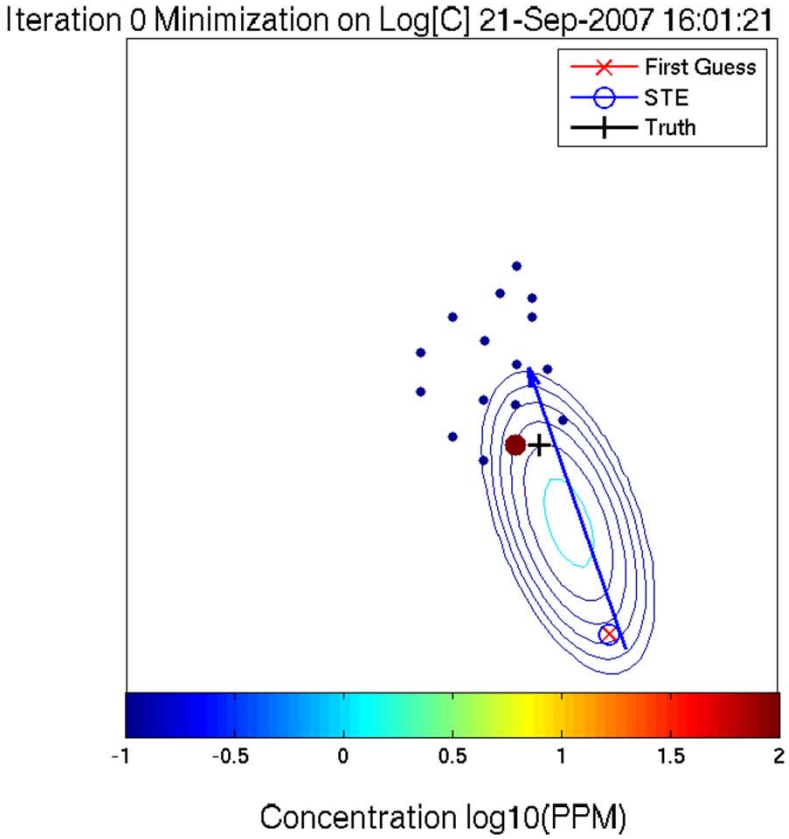
Example FFT07 Case 37

- Reverse SCIPUFF estimated the source **567m** south east from the true release point, release mass was overestimated, but release time was correct

- For demonstration a **+36s** shift was added to the reverse SCIPUFF first guess, before STE.

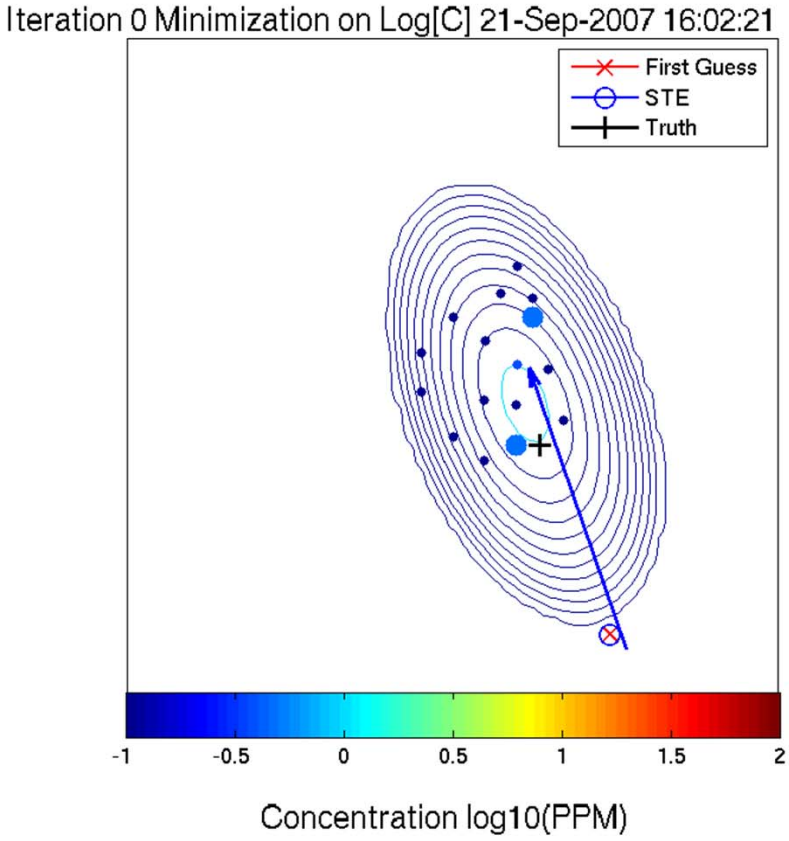
- STE was carried with **10** iterations (7 log + 3 linear) when:
  1) All source parameters $[q_s, x_s, y_s, z_s, t_r, U_e, \theta_e]$ are adjusted,
  2) Release time is fixed, other parameters are adjusted
  3) Wind speed and direction is fixed, other parameters are adjusted

FFT07 Case 37
First Guess



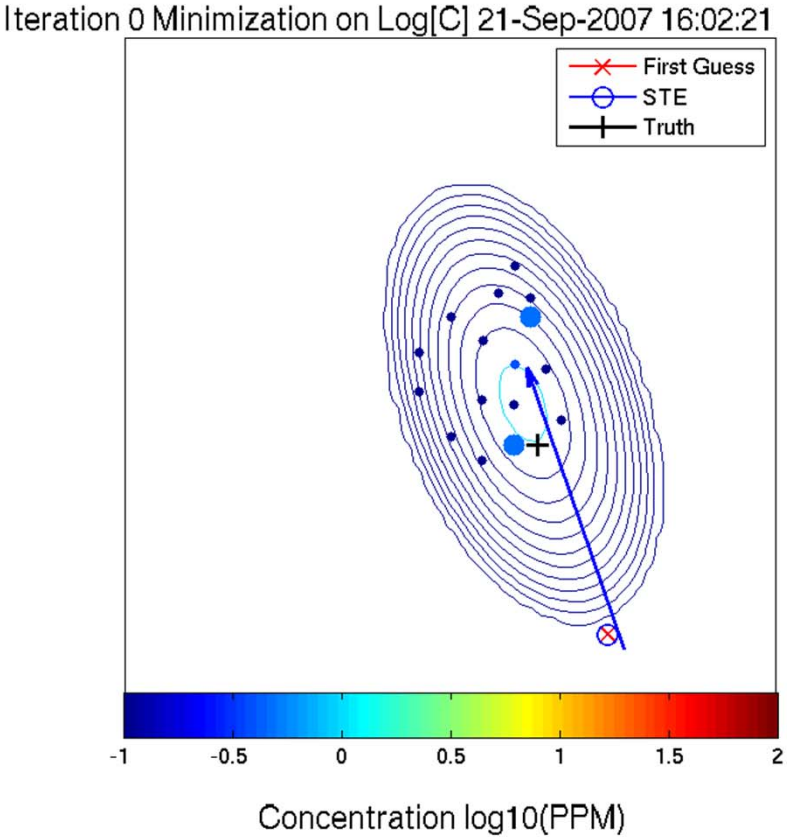
Reverse SCIPUFF located the source (x)
567m South East from the true source (+)

FFT07 Case 37
all $[q_s, x_s, y_s, z_s, t_r, U_e, \theta_e]$ adjustment



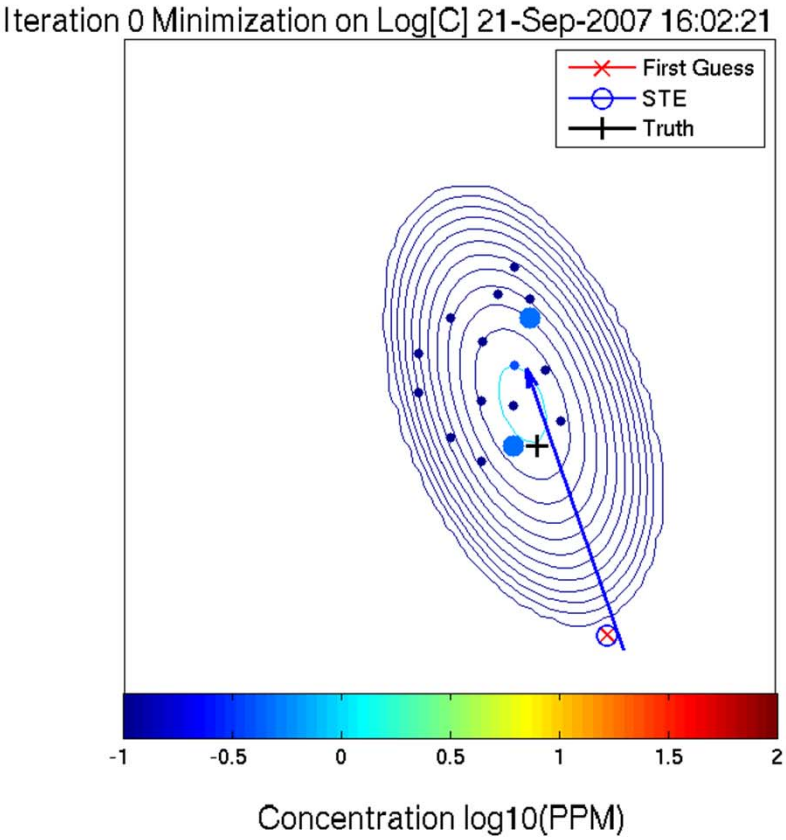
STE (o) moved the source location from SCIPUFF first guess (x) at **79m** from the true source (+)

FFT07 Case 37
NCAR $[q_s, x_s, y_s, z_s, U_e, \theta_e]$ adjustment (fixed t_r = +36s)



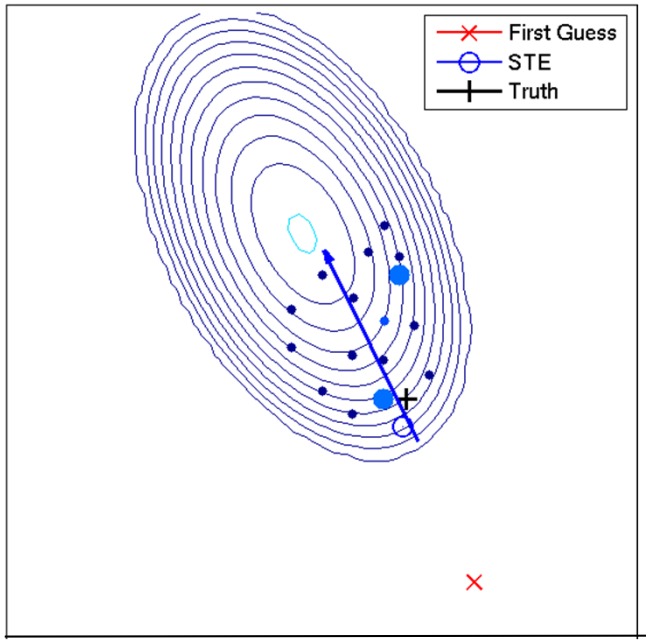
STE (o) moved the source location from SCIPUFF first guess (x) to **99m** from the true source (+)

FFT07 Case 37
$[q_s, x_s, y_s, z_s, t_r]$ adjustment (fixed U_e & θ_e)

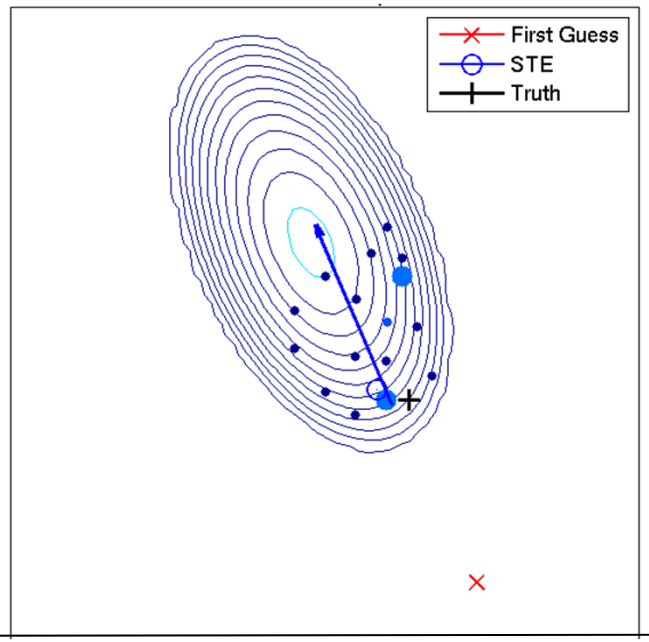


STE (o) moved the source location from SCIPUFF first guess (x) to **224m** from the true source (+)

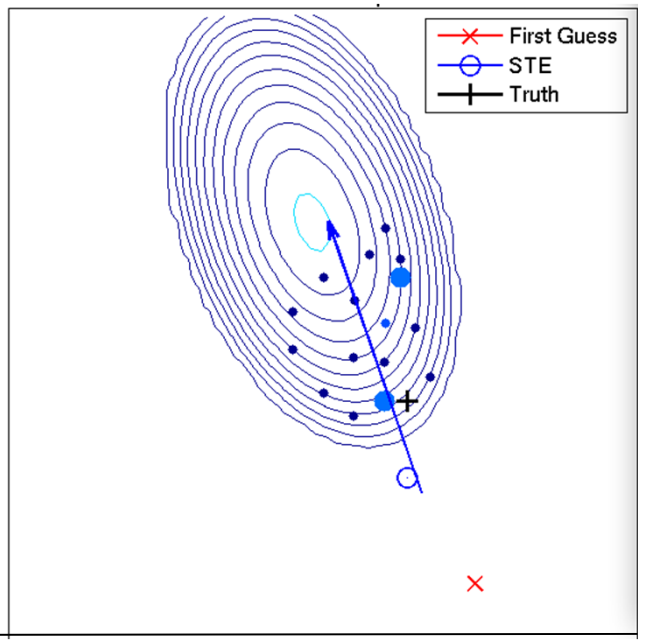
FFT07 Case 37



all parameter estimation
Error = 78m



No time estimation
Error = 99m



no wind estimation
Error = 224m

FFT07 Case 37

	FG	STE	Truth
Q kg/s	5	4.3	4
X m	3013	2814	2826
Y m	1436	1895	1972
Z m	1.6	1.6	1.6
T s	36	9	0
U m/s	6	4.4	??
Θ deg	109	116	??

all parameter estimation

Error = 78m

FG	STE	Truth
5	4.8	4
3013	2732	2826
1436	2005	1972
1.6	1.6	1.6
36	36	0
6	4.0	??
109	113	??

No time estimation

Error = 99m

FG	STE	Truth
5	4.6	4
3013	2819	2826
1436	1748	1972
1.6	1.6	1.6
36	19	0
6	6.0	??
109	109	??

no wind estimation

Error = 224m

Reported observed wind was U = 6 m/s, θ = 109°

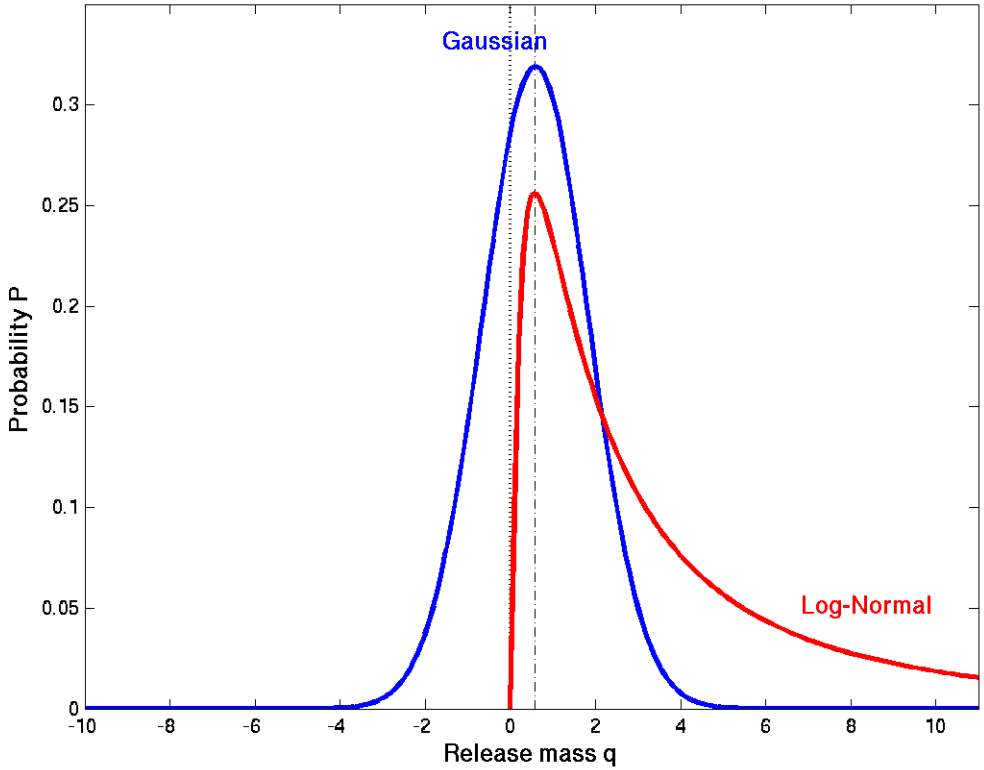
Summary

- All parameter estimation performs best
- Observed winds were not consistent with concentration reports
- Accurate release time seems less important than accurate winds
- Mass estimation must be improved

Current Work

1)Use of lognormal PDF for mass and concentration:

- One minimization for all
- No negative values



Next

- **Better characterization of uncertainty through the σ's**
- **Addition of correlations, e.g. wind/position errors**