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Interactive comment on "Optimization of an Urban Monitoring Network for Retrieving an Unknown Point Source Emission" *by* Hamza Kouichi et al.

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The manuscript highlights an interesting and challenging problem related to the optimization of sensor networks in the context of a point source reconstruction. In general, the optimization of monitoring network consists of two important issues: (i) reducing the number of receptors and (ii) finding an optimal design of the arrangement of the monitoring network. Here, the study deals only with selecting a reduced set of number of receptors among an already established monitoring network, which is very limited form of a real problem.

The authors have already published the inversion methodology and simulated annealing algorithm (SA) with its application to wind tunnel experiment in Kuichi et al. (2016).

The present study shows a similar application in an urban terrain field experiment by using a CFD model. It does not involve any new development in the model or inversion / optimization algorithm. The presentation of the results is classically similar to a point source reconstruction study which do not highlight any significant contribution related to optimal networking. The application of renormalized inversion and SA methodology in optimizing receptors are associated with several issues which are not clarified in the text. Besides, there are several examples of uncleared and overstated sentences, misinterpretation of mathematics, poor description of results and methodology. Overall, it needs to be justified that what is the significant outcome of this study and how their approach of determining optimal network, which is biased towards measurements, is justified in a general framework?.

Following are the major comments related to the manuscript:

General Comments:

1. In network optimization problem, finding an optimal rearrangement of a set of receptors and then, their evaluation for source estimation are two independent set of problems. The determination of optimal rearrangement should be performed independent of knowledge of measurements and it must contain available maximum information in the domain regarding observability of emissions. The second problem regarding evaluation of source retrieval should be carried out as a next step to validate the efficiency of such networks in the presence of random model-measurement errors. In this study, the two set of problems are mixed and arrangement of network is determined given the knowledge of measurements which is a biased choice of receptors. In addition, the study does not discuss any criterion which could quantify the information in a particular design or impact of model-measurement errors on the chosen network.

2. Through out the text, authors have mentioned the keyword "optimal network". A big question here, is how to prove that a particular design is optimal?. This requires rather mathematical or statistical arguments / proofs to support the fact that a design

is optimal. This can not be shown by showing source retrieval which is nothing but just the estimation of 3 parameters (location, (x, y) and strength q).

3. A big limitation of this approach is the subjectivity and biasness in the methodology and their dependence on the measurements. The optimality of the reduced set of receptors is shown based on the accuracy of the point source retrieval which is not relevant. The good retrieval results with presumed lesser number of receptors are not surprising since their chosen cost function depends on the measurement's values which always force the SA algorithm to choose the receptor locations with good model-measurement accuracy. They completely ignored the fact that their network design criterion should be independent and prior to the knowledge of measurements, which is one of the big limitations.

To be precise, the optimization methodology utilizes the same cost function for both the tasks: (i) Identifying a reduced set of receptors and (ii) retrieving the point source parameters. The cost function utilizes the actual measurements and measures the deviations between measured and predicted concentrations at the chosen set of receptors. The iterative SA algorithm tries to minimize this cost function, which means it selects the receptors with good model-measurement accuracy, i.e. which are closer to the measurements. This will eventually results in good retrieval depending on the model error. This clarifies the fact that the choice of receptors is always subjective to the model-measurement accuracy and will vary in case of perturbation in the model-measurement variables. Thus, this is a poor approach and always biased towards model-measurement accuracy which do not signify the objective of optimization of receptors. The optimization of receptors should have performed independent and prior to the knowledge of measurements, which is not done here.

4. The study do not provide any insights / discussion on systems observability while remaining ill-posed, quantification of information gain or loss during optimization of the network, statistical or mathematical criterion leading to network optimization and sensitivity of the network design with respect to the perturbation in the model-measurement

variables. Also, the study do not mention any optimality criterion, design of experiment or information theory criterion.

5. Another issue with the methodology is that the SA algorithm may not converge always to the same set of reduced receptors. More often, there is high probability that the reduced set will change in every repeated simulation since the number of possible combinations are really high. In this case, how do you guarantee the optimality of design?. Also, the authors never compared between various such different sets corresponding to same trials as how they are varying or what are the differentiation between them. It seems that the authors just choose the arrangement with least reconstruction error which is not logical.

6. If the objective was simply to have a reduced set of network where model-measurement errors are minimum (which is done here), why authors just did not select those locations where model predictions are matching with measurements ?. This could be done simply by comparing model predictions and measurements instead of a massive SA computation. Based on the proposed approach, this can not be called an optimization of the monitoring network.

7. The proposed approach also raises questions regarding the efficiency of the network in case of perturbed model-measurement fields/variables. Also, the retrieved parameters are highly sensitive toward the design of their network which raise further questions regarding the efficiency of the chosen network. The optimized choice of network will always be subjective with respect to the wind variability, model, model errors and measurements. In trials, where model does not perform well, the error will always be high, for example see in trials 2. This will raise the issue of failure of their monitoring networks in identifying correctly the emissions in case of large model errors. This is why the arrangement of the receptors vary in all the trials, even when in some trials, the wind conditions are approximately similar.

8. The study also discusses about weights which they, later, referred as visibility func-

tions highlighting prior informations regarding emissions. However, authors never mention "why they could not determine a criterion based on just visibility weight functions"? Which could be far relevant and independent to the measurements.

9. It is not clear why they could not find a common optimal network which could work in all the trials for point source retrieval ?. The original network of 40 receptors was already working in all the trials irrespective of model errors and varying meteorological conditions. It is useless to propose different configurations based on different meteorological conditions since meteorology can never be constant in a real scenario. The different configurations for different trials again highlight subjectivity of their approach. Thus, the study do not bring any significant outcome regarding the optimization of receptors.

10. How do you describe physical features and efficiency or quality of the reduced configuration?. This is never mentioned in the results and discussion. The discussion mainly involves only source retrieval.

11. Why their optimization always results in finding most of the sensors (5-6 detectors in the reduced configuration) close to the source location? It was never explained in the text. Does your optimized choice of receptors depends significantly on the receptors closer to the source location?. If yes, then what is use of optimizing since you will never know the source in accidental scenarios?

12. Why signal to noise ratio is not shown for all the reduced configurations? and it should be compared with the original network?

13. The authors have simply described the errors in retrieving the location and intensity of the source. The responsible reasons behind it were never explained?. This shows that authors are just interpreting the retrieval rather than really analyzing the results.

14. What is the role of weight function in your reduced configuration?. Does it have any effect on the systems observability and how it do affect your retrieval?

15. Why did you describe vector s on the figures of the source retrieval?. While it seems that you are retrieving source parameters in a weighted least-squares framework?. It was never explained in the results that what is the impact of reducing the receptors on the retrieved general source vector?.

16. A general choice of using a weight matrix in a least-squares methodology is measurement error covariance matrix. Authors did not justify how could they utilize matrix Hw as an alternative to measurement covariance matrix?. In addition, the Hw matrix is not a diagonal matrix which means that using Hw as a weight matrix will induce unphysical correlations among receptors which could be false as well. Did you analyze their impact on source retrieval?, If not, then why and how could you use them directly? Perhaps, you could assume an unity matrix. If not, why?

17. Another issue is with the presentation of the methodology. The study begins by posing an under-determined inverse problem of estimating state of emissions while their objective was to optimize a reduced set configuration for point source retrieval which is an overdetermined inverse problem. Why authors did not begin by directly posing the over-determined problem of point source retrieval?. Why they have presented unnecessary details regarding more general inverse problem of estimation emission state if it was not their objective?. The presented details were already published by several researchers in the literature. Further, authors again formulate the point source retrieval problem in a weighted least-squares sense. Why?. Why two different methods were presented for the same problem?.

18. Why do you need to compute a general vector s of state of emissions?. The objective was just to estimate point source parameters which could be estimated with the weighted / non-weighted least-squares method?. Please clarify?.

19. Again, in the results, figures highlights distribution of weights and vector s which was never related to their monitoring network optimization. Their presentation confuses the overall objective of the study. Do you propose an optimal design for point

source retrieval or a general source retrieval?. The figures related to weights are never explained as why they were needed? or what information do they provide related to the monitoring arrangement?. The given explanation is just copy-paste from previous papers of the authors.

20. Why authors did not compare the weights in comparison to their weights corresponding to the original receptors?.

21. Another issue is also related to the common base network among the 10 and 13 sensors network. Why their strong base network involves only 7 receptors? In general, the 10 sensors networks should be a subset of the 13 sensor network, if not then why?. Please clarify?. It is also surprising that in some trials the common base network involves only 3 sensors. This is unusual having so much variation in having common base sensors among 10 and 13 sensor network in trials. The authors should provide the reasoning behind?, not just mentioning the results.

Specific comments:

1. Abstract, Page 1, line 7. The sentence "The optimal networks in the MUST urban regions enabled ...". Rephrase the sentence. How could an optimal network enable a reduction?. I would like to mention again that the reduced set of receptors were never proved optimal.

2. Abstract, Page 1, line 11. The sentence "This study presents first application of the renormalization data assimilation approach for the optimal network design . . ...." is overstated and wrong. I could not find where and how did you apply renormalize data assimilation for optimal network design. Renormalize assimilation is only for retrieving the source parameters. I do not see in the text, how it could retrieve the reduced set of receptors. Also, you have interpreted a least-squares framework without justifying their inherent equivalence and choice of parameters with respect to the renormalization. Why?.

3. Page 1, line 18, the sentence "However, pre-deployment of these limited number of sensors . . ...". Please clarify, how could a pre-deployment of sensors helps to achieve maximum information from set of noisy concentration measurements. The objective of pre-deployment of sensors is to have maximum a priori information regarding state of emission and to correctly capture the data while extracting and utilizing information from the data is the final task of data fusion techniques.

4. Page 2, line 2. The sentence "detection of an unknown continuous point source's parameters ..." is wrong. How could you detect point source parameters? They are rather retrieved or estimated.

5. Page 2, line 12. See the sentence "The establishment of an optimal network requires...". Why do you think that for an optimal network it requires availability of concentration measurements?. Please justify? Measurements may be required for the evaluation or validation but for establishment a network can be made with the meteorology and dispersion model.

6. Page 2, line 20, See the sentence "This approach includes the geometric and flow complexity inherent . . ...". I do not think if there is any inverse approach which includes such things for optimization process. The flow variables are accounted through the model, perhaps in the inverse approach in the form of sensitivities which is also derived from adjoint model. All the STE approach can include such information from model.

7. Page 2, line 26. What is "regularized norm square". I do not think Sharan et al., 2012 have included such terms.

8. Page 3, lines 3-5. Issartel, 2005, Sharan et al., 2009, 2012 and Kumar et al., 2015b, do not discuss any iterative algorithm to minimize the difference between observed and modeled concentration.

9. Page 3, line 8, "does not required". Please correct the sentence.

10. Page 3, lines 16-17, Kumar et al. (2015b, 2016) do not provide any extension to

renormalized inversion. It was just an application with CFD model.

11. Page 3, lines 22-29. The authors defined the objective to determine optimal network but never achieved. In line 23, "A methodology was proposed ....". If the objective was to better characterize the source, why one need to reduce the number of receptors. The reduction of receptors simply refers to the reduction of information regarding the observability of state of emissions. In line 26, "For this purpose ...., but with comparable information". Where do you show in the manuscript that the reduced information is comparable to the original network. In line 27, "This work explores with two requirements ......", What does it mean, there is no movement of sensors. You have performed only selection of sensors.

12. Page 4, line 2, please correct "concentrations measurements".

13. Page 4, line 4, please correct "an horizontal plane".

14. Page 4, lines 8-10, The sentence "This study deals with linear relationship, as except from the nonlinear chemical reactions ....." is wrong. Most of these process are nonlinear in your case due to complex flow structures.

15. Page 4, line 26, citing Kumar et al., 2016 is not appropriate. Please cite appropriate reference.

16. Page 4, lines 28-30, I understand that the inverse solution from Eq. (2) will lead to peaks at the grid cells coinciding with the measurement cells. This is obvious since the sensitivity matrix has peaks at the measurement cells which are reflected in the inverse solution. However, the difficult part to understand is "why do you call these large values of sensitivities at measurement cells an artificial information? Or a virtual/unphysical reality?". The peak at measurement cells is obvious since the concentration is always maximum at source location and in adjoint computations, you have replaced your measurement cells as source. Please clarify.

17. Page 5, line 5, Why do you think that normalizing peaks in the sensitivity matrix

with weights will cure the peak problem. I mean, even if you normalize peaks (infinitely large value) by some nonzero weight values, it will not change anything.

18. Page 5, line 9, citing Kumar et al., 2016 is not appropriate. Please cite appropriate reference.

19. Page 6, line 3, "but with comparable information". It is never done in the study.

20. Page 6, line 4, "delivers maximum of the information". It is never shown in the study.

21. Page 6, line 11, why cost function is defined according to Hw norm. Please clarify?.

22. Page 6, line 12. Check sentence "As the cost function is convex, its minimum value must correspond to the maximum intensity of the source". WHY?. Please clarify?. The intensity of source here is q. Check your mathematical expressions. You will obtain an estimate of q for each location vector x. In such case, the maximum value of q in the domain may go to infinity in case where weights w are very small or zero. It is not necessary that the maximum value of q will occur at the minimum of the cost function or at the source location.

23. Page 6, line 15. This is not clear how you can utilize matrix H_w in place of measurement error covariance matrix in Eq. (9). This is not obvious. Justify?.

24. Page 6, line 16, why two notations q and q0 (section 2.4) are utilized for the same representation?

25. Page 6, line 19, "conditions of maximum intensity....". It seems that authors have difficulties in understanding mathematics. Why equating first order derivative to zero will give maximum intensity?

26. Page 6, line 25, The expression for equation (13) is wrong. Please correct it.

27. Page 6, line 26. The mathematical expression is wrong.

28. Page 6, line 27. How do you guarantee the global minimum in SA algorithm?.

29. Page 7, line 16, “average of the difference of the cost functions calculated for a large number of cases”. How did you compute it?

30. Page 7, line 19, “An equilibrium is reached . . ...”. This means that the SA algorithm stops when cost function becomes constant. Then how do you prove global minimum?

31. In combinatorial optimization problem, it is not necessary that SA will provide the same solution or same set of receptors as the converged solution. In this case, how did you choose the solution?.

32. Page 8, step 2 and step 3 show that the choice of receptors depends on the measurements. Thus, there is no optimality in network. The authors have simply chosen the reduced set of receptors based on good retrieval results which is biased.

33. Page 9, lines 8-11. These are not clear. What do you mean by near-optimal network?. What are the conditions for “near overall optimum condition”.

34. Page 11, line 11, “The network optimization process . . ...”. This shows that the choice of receptors are biased towards the model-measurement accuracy.

35. Why the configuration of networks should vary based on meteorological stability conditions.

36. Page 12, lines 8-9. “These results exhibit that the SA . . ...”. How it prove optimality of monitoring network?

37. Page 12, line 19. “were observed independently of the number of sensors”. Why?. Please clarify?.

38. Page 12, line 20, “larger location errors do not . . ..”. Why?. Please clarify?

39. Page 12, line 23, “a large number of sensors are close to the source positions ..”. Why so?. Please justify?.

40. Page 12, line 29, “visibility functions have significant levels . . ...”. What does this mean?.

41. Page 13, line 6, “increase in the number of sensors in a network has little influence on the accuracy. . ..” Why? Please clarify?

42. Page 13, lines 8-10, “In some trials, it was also noted . . ...not necessary benefial.” How could you justify this?. In fact, how did you evaluate if information added by a sensor is fruitful or not? If just based on accuracy of source retrieval, then it is illogical? If an information added by a new sensor is not beneficial then why it should increase the location error?. Also, how location error may decrease with decreasing the number of sensors? You can say this just because you are looking at source retrieval estimates. However, reducing the receptors will make the source retrieval unstable and more sensitive to the noise.

43. Page 13, line 17, What do you mean by “. . . diversity of structures independently of the number of sensors.” You computation is based on fixed number of sensors and there is no discussion of diversity. However, in the following explanation, this is not understandable that why you have different number of common networks in different trials?. It seems that optimized choice of receptors is not really optimized. Otherwise, why in some trials (1, 11), only 3 sensors are found as a common base?. Also, even having 7 receptors as common in 10 and 13 sensor arrangement can not be called a strong common base. There is no explanation why all the 10 sensors are not subset of 13 sensor network. If, it was really optimized that it must have been. If not so, then please explain why?

44. Page 13, line 22, “The performances do not systematically converge independently to the size of the networks”. What does it mean and why it does not converge?. Further, it is mentioned that in trial 1, 13 sensor network leads better performance than a 10 sensors network and algorithm leading to near global optimum is contained in the 13 sensor network. This really proves that fact that you choice of receptors is biased by

your source retrieval which is not the objective of an optimal network.

45. Page 13, line 27. Why there is no common trend in skeleton network observed in several trials?. There must be at least with similar flow conditions. If not, justify?

46. Page 13, line 29, “optimal networks can satisfy conditions of a near overall optimum (to be minimized)”. What are the near overall optimum conditions?. If you are referring “minimization of cost function”. This is a wrong approach.

References:

1. H. Kouichi, G. Turbelin, P. Ngae, A. A. Feiz, E. Barbosa & A. Chpoun (2016), Optimization of sensor networks for the estimation of atmospheric pollutants sources, WIT Transactions on Ecology and The Environment, Vol 207, doi:10.2495/AIR160021.

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