An Efficient Ensemble Data Assimilation Approach To Deal With Range Limited Observation

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Outline

- Motivation
- Range Limited Observations (RLO):
  - Methodology and Algorithm
- Numerical Experiments
- Conclusion

Motivation

- Many available measurement in environmental systems are defined within certain interval.
- To use the qualitative information available from the range limited observations.
- Very few studies carried out dealing this issue Borup et. al., (2015)

Range limited Observations

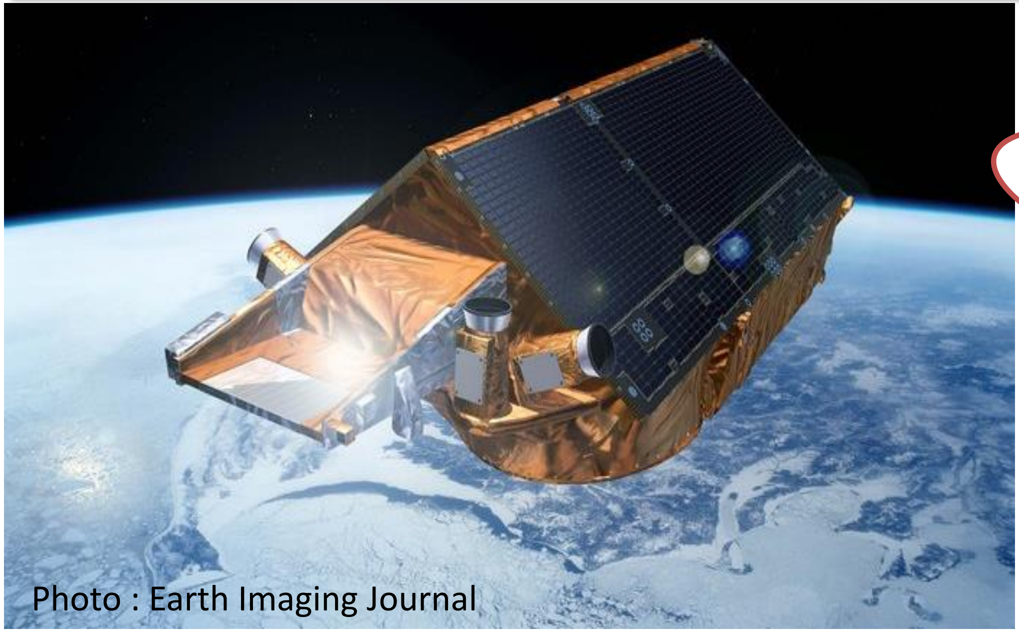


Photo : Earth Imaging Journal

Sea-ice thickness only up to 50cm

Soil moisture only up to 5cm

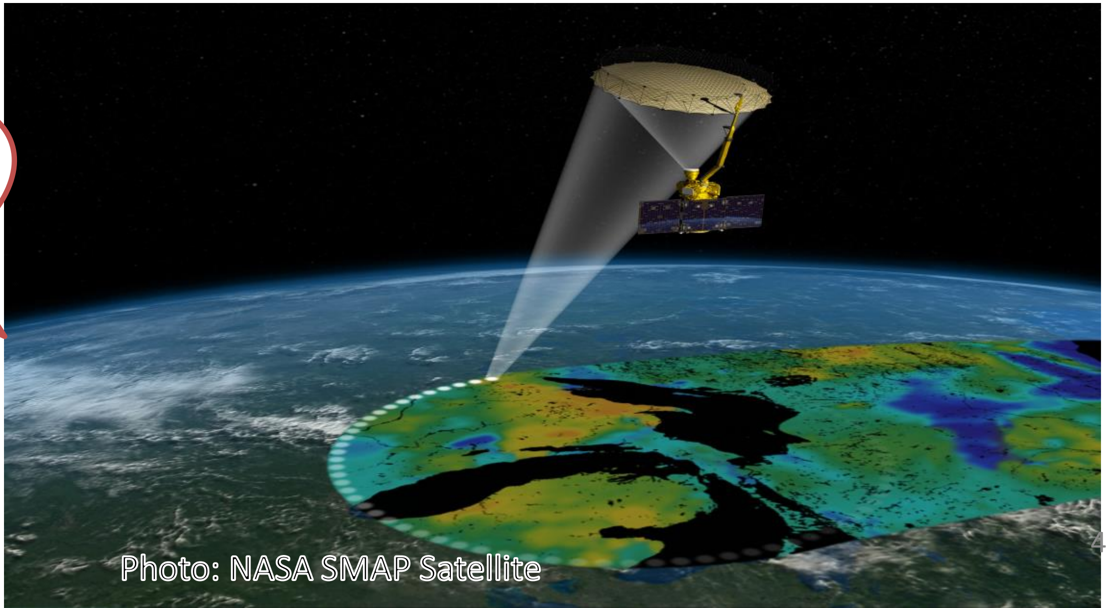


Photo: NASA SMAP Satellite

Methodology and Algorithm

- Bayesian Rule

$$\mathrm{p}(\boldsymbol{x} \mid \boldsymbol{y}) = \frac{\mathrm{p}(\boldsymbol{x})\,\mathrm{p}(\boldsymbol{y} \mid \boldsymbol{x})}{\mathrm{p}(\boldsymbol{y})}$$

- Borup et. al., (2015):
  - Ensemble Partial Updating (EnPU) for RLO
  - EnPU will allow us to use qualitative information about data i.e., the posterior will be

$$\mathrm{p}\left(\mathbf{x}_{\mathrm{k}} \mid \mathbf{y}_{\mathrm{quant}}, \mathbf{y}_{\mathrm{qual}}\right)$$

where $\mathbf{y}_{\mathrm{quant}}$ and $\mathbf{y}_{\mathrm{qual}}$ are quantitative and qualitative observation respectively

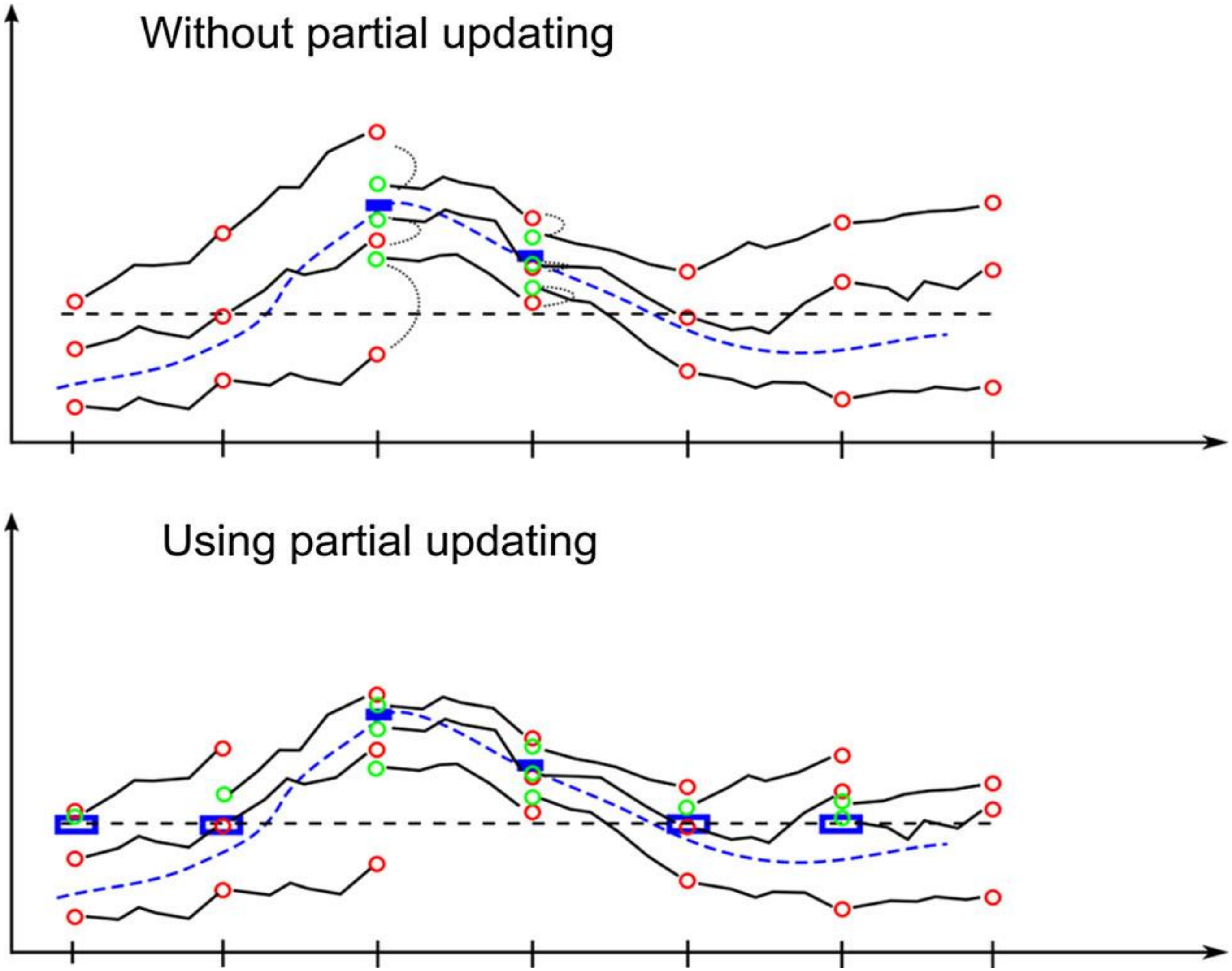


Figure : (Borup et. al., 2015) With and without partial updating when the measurement gauge has lower observation limit

Partial Ensemble Kalman Filter (PEnKF)

- OR-observation
  - ➢ Create virtual observation at threshold limit
  - ➢ Data likelihood for perturbing observations
  - ➢ Two Piece Gaussian distribution (Fechner's Kollektivmasslehre, 1897)
  - ➢ One of the observation variance in 2-piece Gaussian

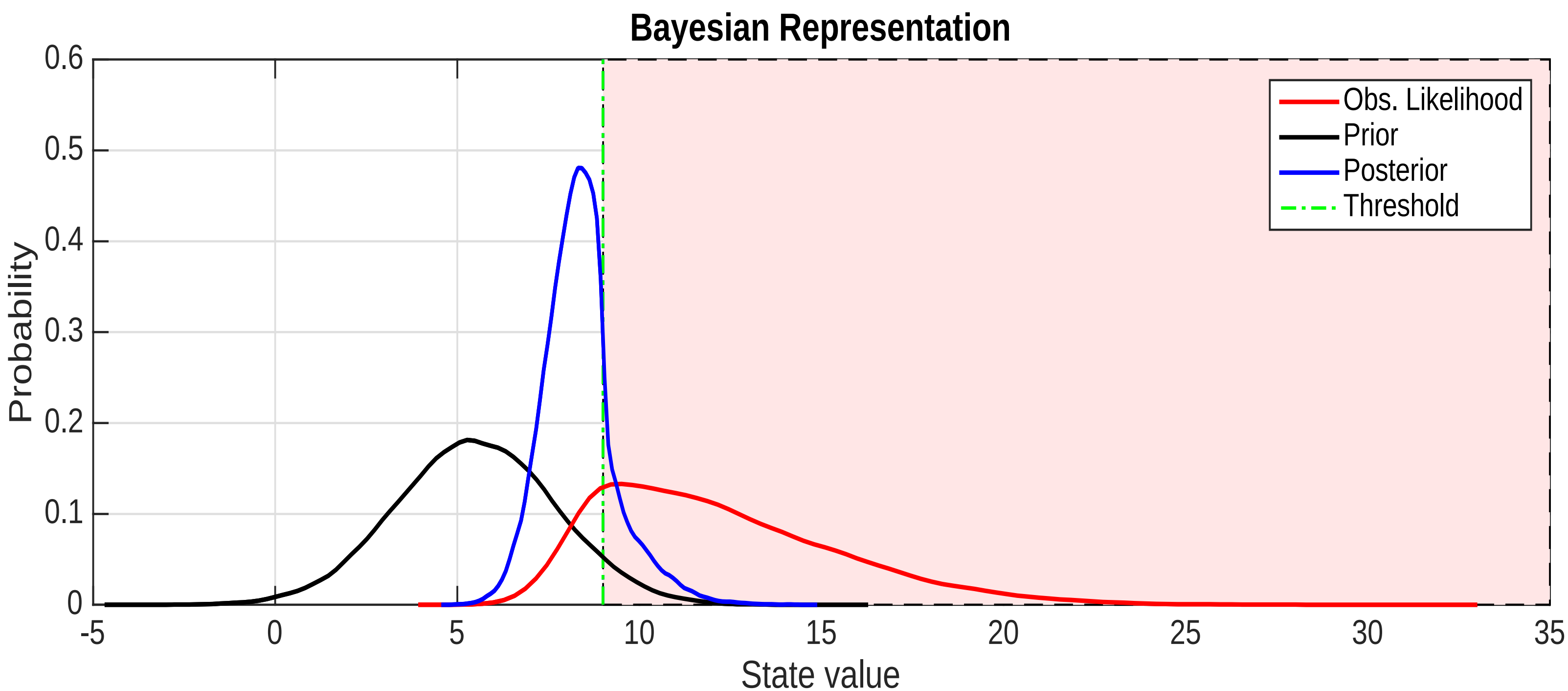
$$s_{or} = p * \left(\mathbf{H}\overline{\mathbf{x}}^{f} \right)$$

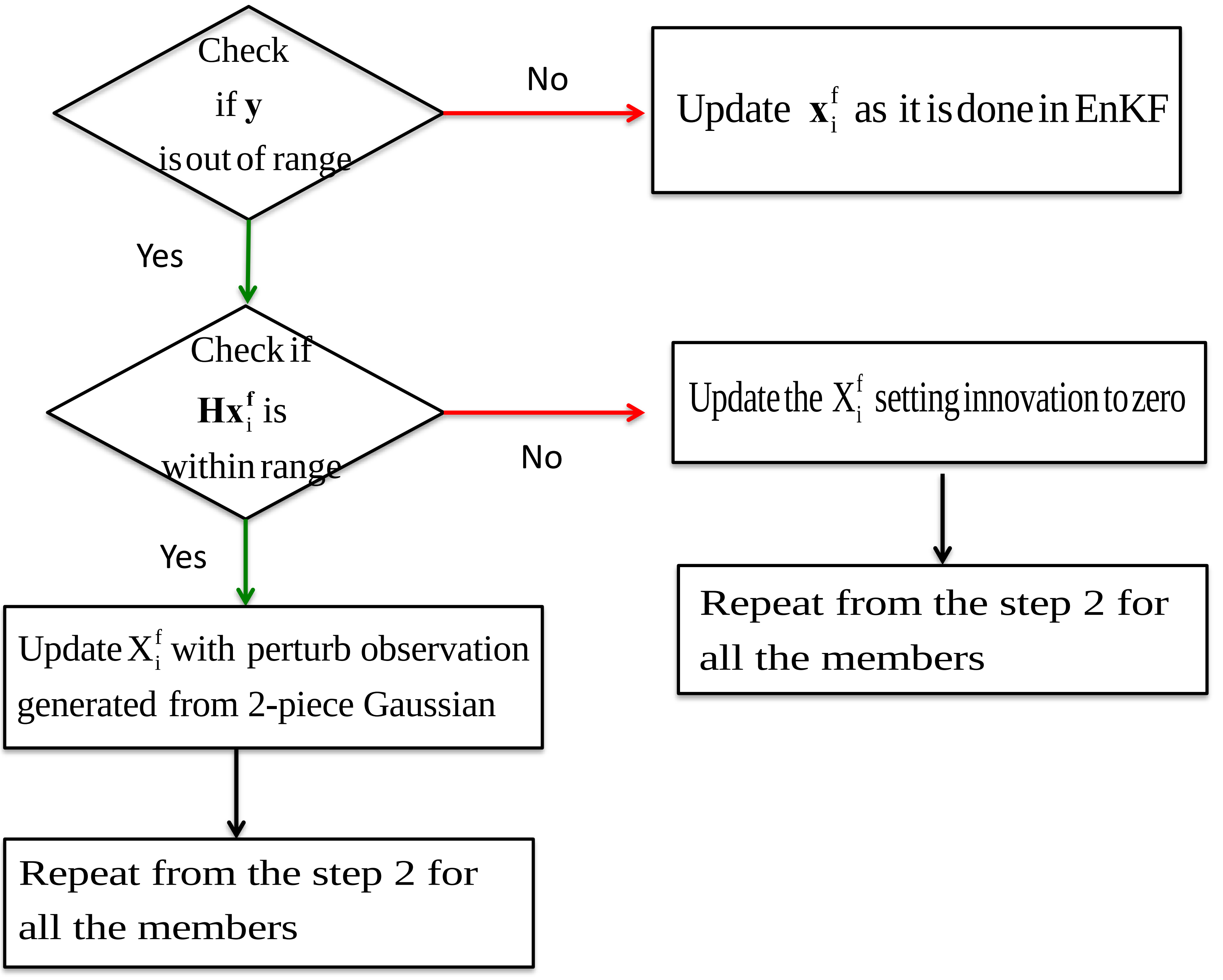
where p is positive real number

Cont..

- Posterior when the prior is in-range

$$p\left(\mathbf{x}_k \mid \mathbf{y}_{quant}, \mathbf{y}_{qualit}\right) \propto \begin{cases} p(\mathbf{x}_k)p(\mathbf{y}_{quant} \mid \mathbf{x}_k) \\ p(\mathbf{x}_k)p(\mathbf{y}_{qualit} \mid \mathbf{x}_k) \end{cases}$$




Check if $\mathbf{y}$ is out of range
No
Update $\mathbf{x}_i^f$ as it is done in EnKF
Yes
Check if $\mathbf{Hx}_i^f$ is within range
No
Update the X_i^f setting innovation to zero
Repeat from the step 2 for all the members
Yes
Update X_i^f with perturb observation generated from 2-piece Gaussian
Repeat from the step 2 for all the members

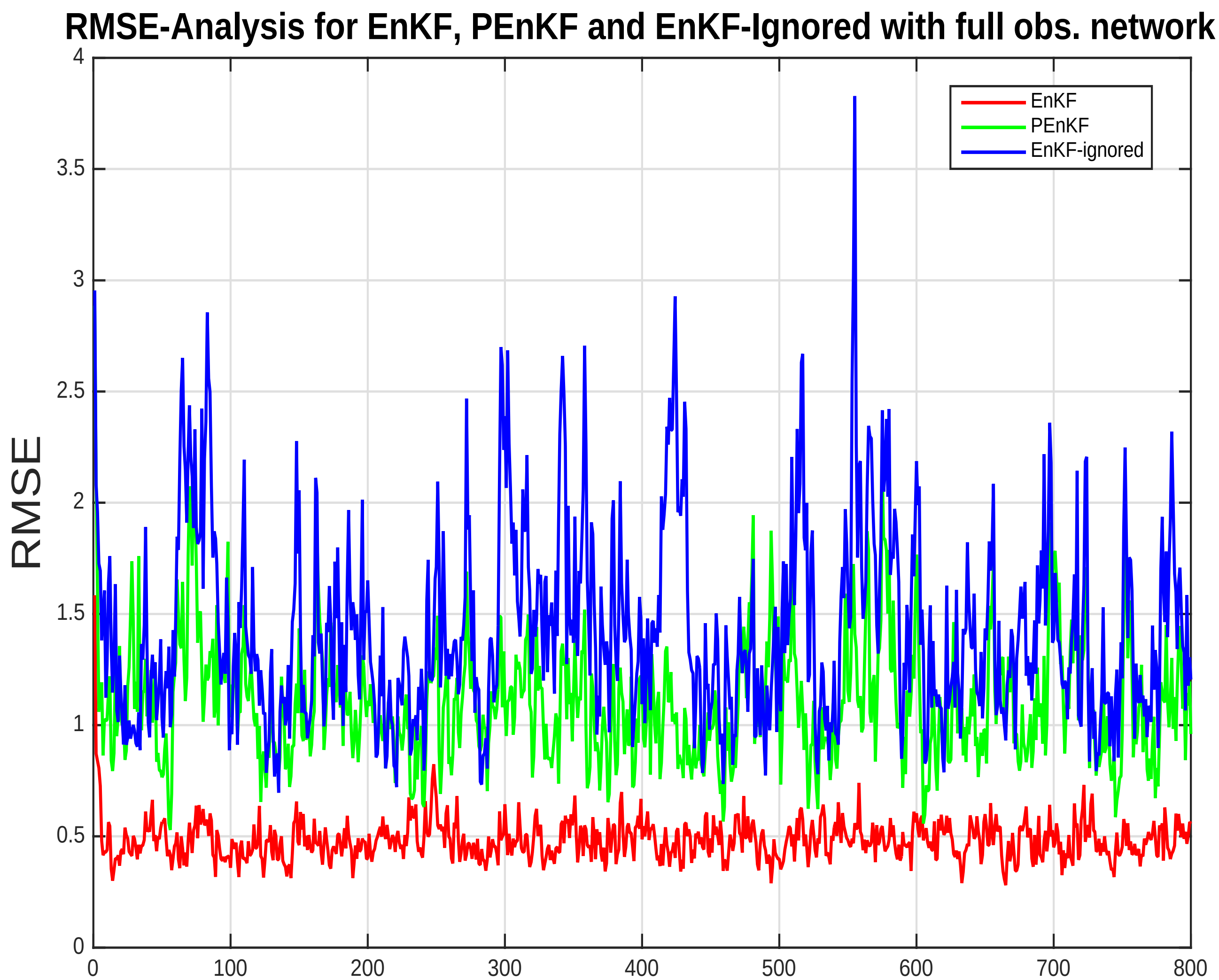
Numerical Experiments

- EnKF, PEnKF and EnKF-ignored DA methods are tested under the framework of twin experiment.
- Model – Lorenz ’96 with configuration as below
  - Number of Ensemble – 100
  - dt - 0.05 (~6 hours)
  - Total time of integration is 5 Years
  - Model error introduced by using wrong forcing - 7.5
  - $s_{obs} = 1$

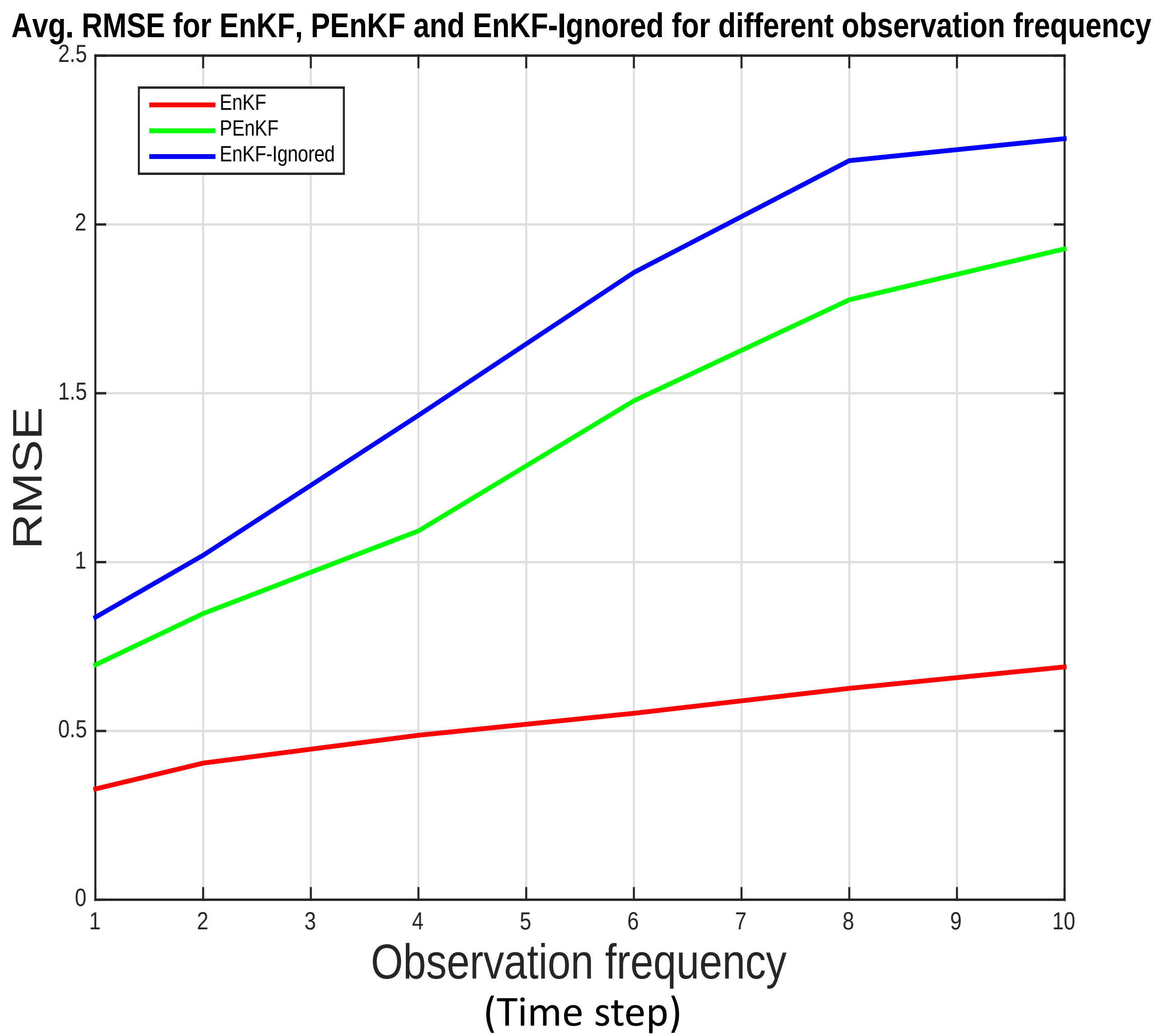
Cont..

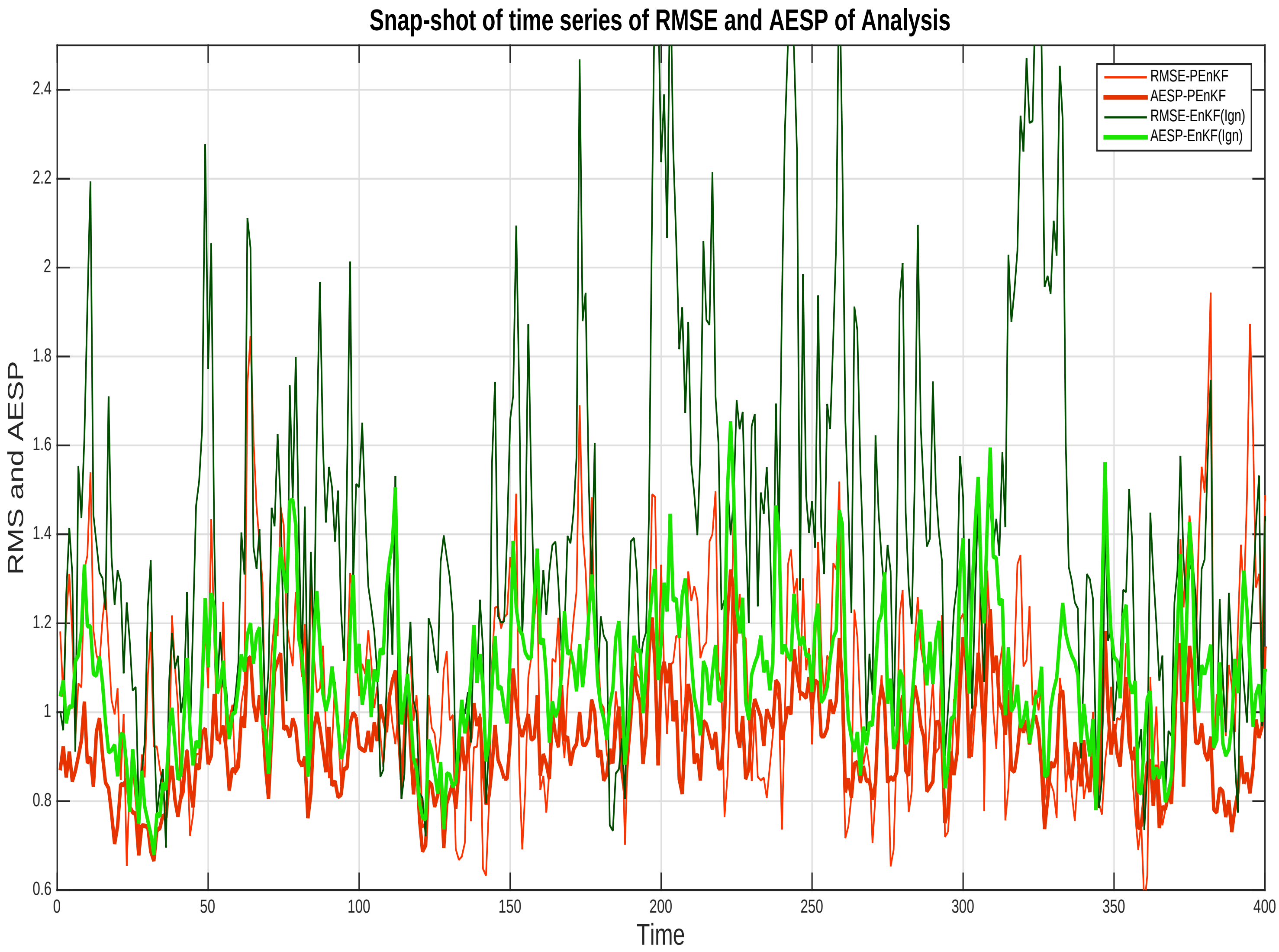
- Experiments for Sensitivity to
  - Number of observation
  - Observation frequency
  - Threshold limit
  - Model error
- Diagnostics tools:
  - Root Mean Square Error
  - Average Ensemble Spread
  - Observation Influence
  - Rank Histograms

RMSE and Avg. Ensemble Spread

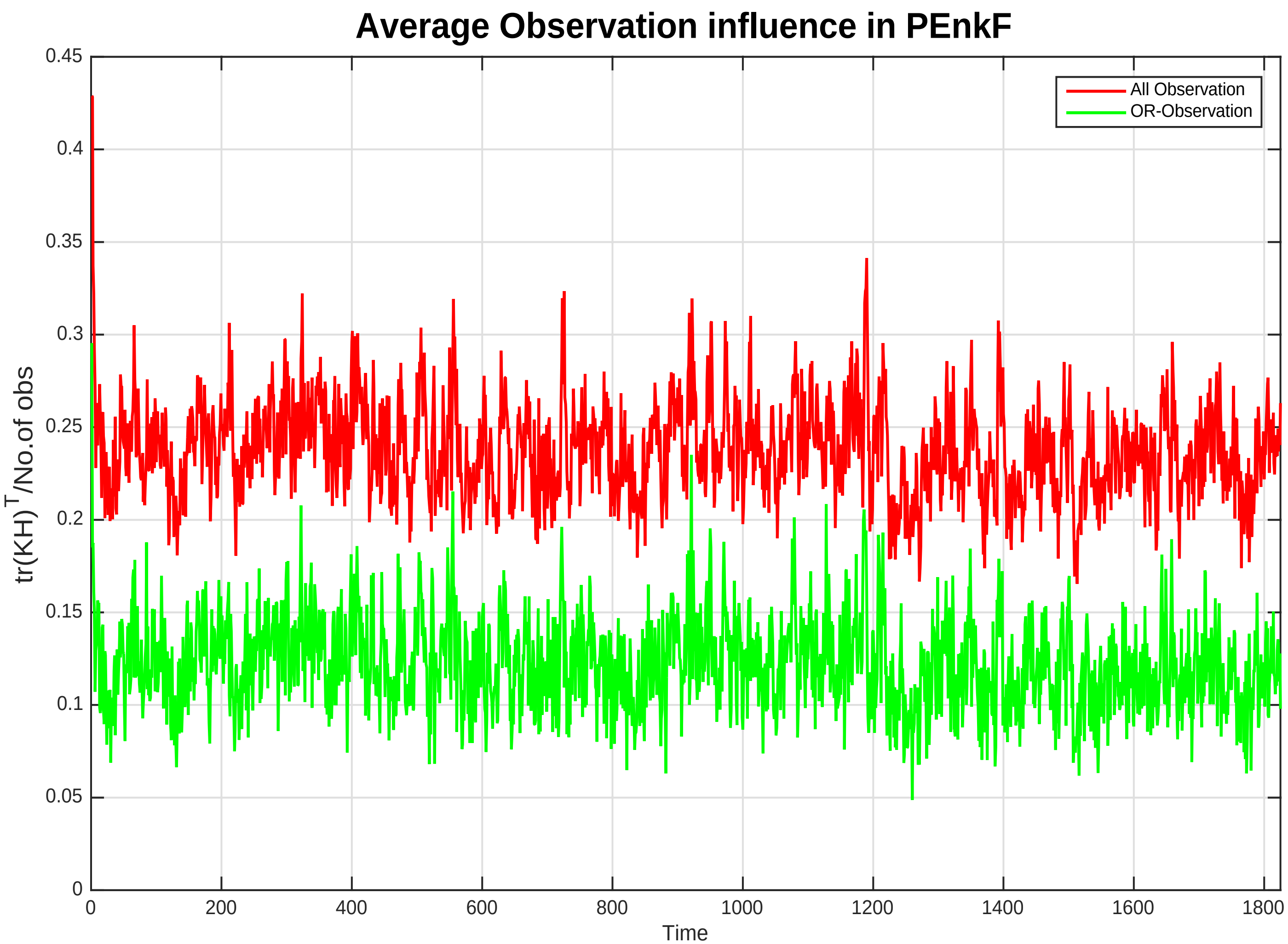


75% of observations are out of range on an average for total time of integration

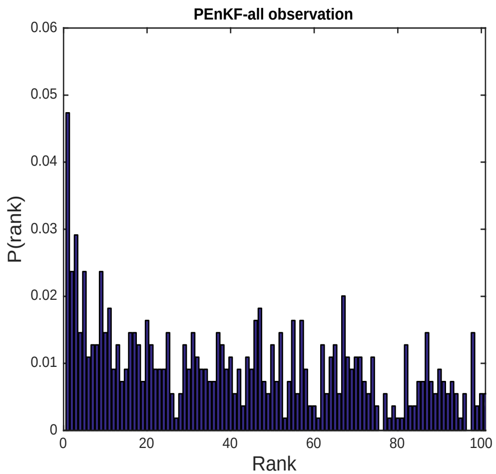

Avg. RMSE for EnKF, PEnKF and EnKF-Ignored for different observation frequency
EnKF
PEnKF
EnKF-Ignored
RMSE
0
0.5
1
1.5
2
2.5
1
2
3
4
5
6
7
8
9
10
Observation frequency
(Time step)

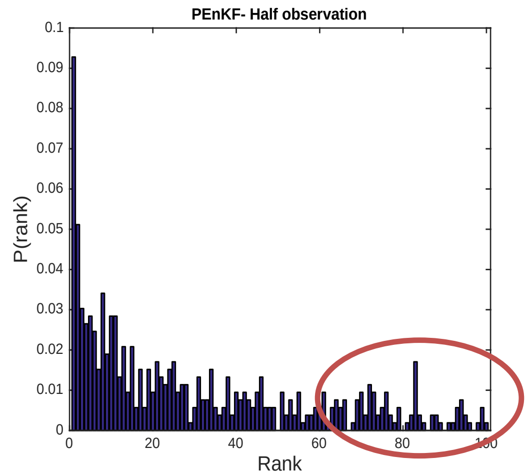

Snap-shot of time series of RMSE and AESP of Analysis
RMS and AESP
Time
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
0
50
100
150
200
250
300
350
400
RMSE-PEnKF
AESP-PEnKF
RMSE-EnKF(lgn)
AESP-EnKF(lgn)

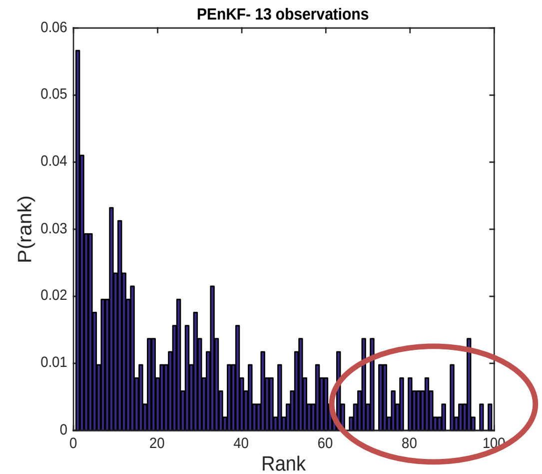
Observation Influence

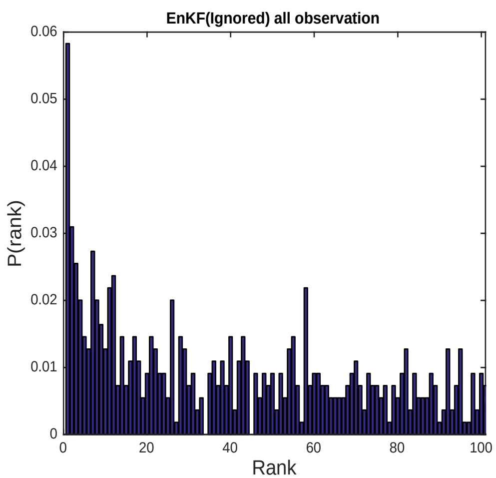


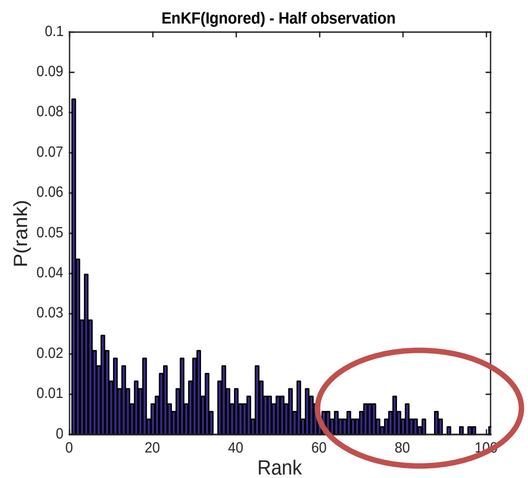
Rank Histogram(Reliability)

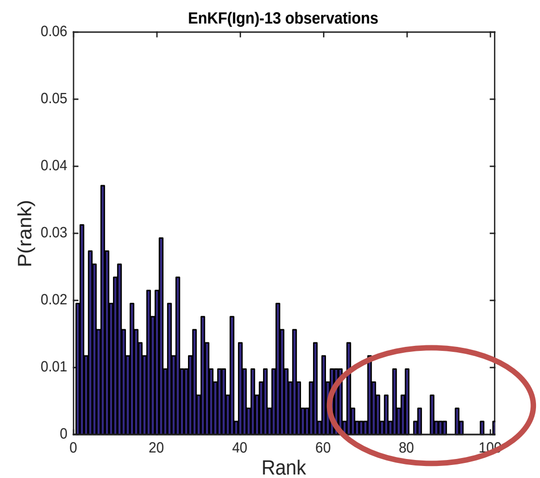




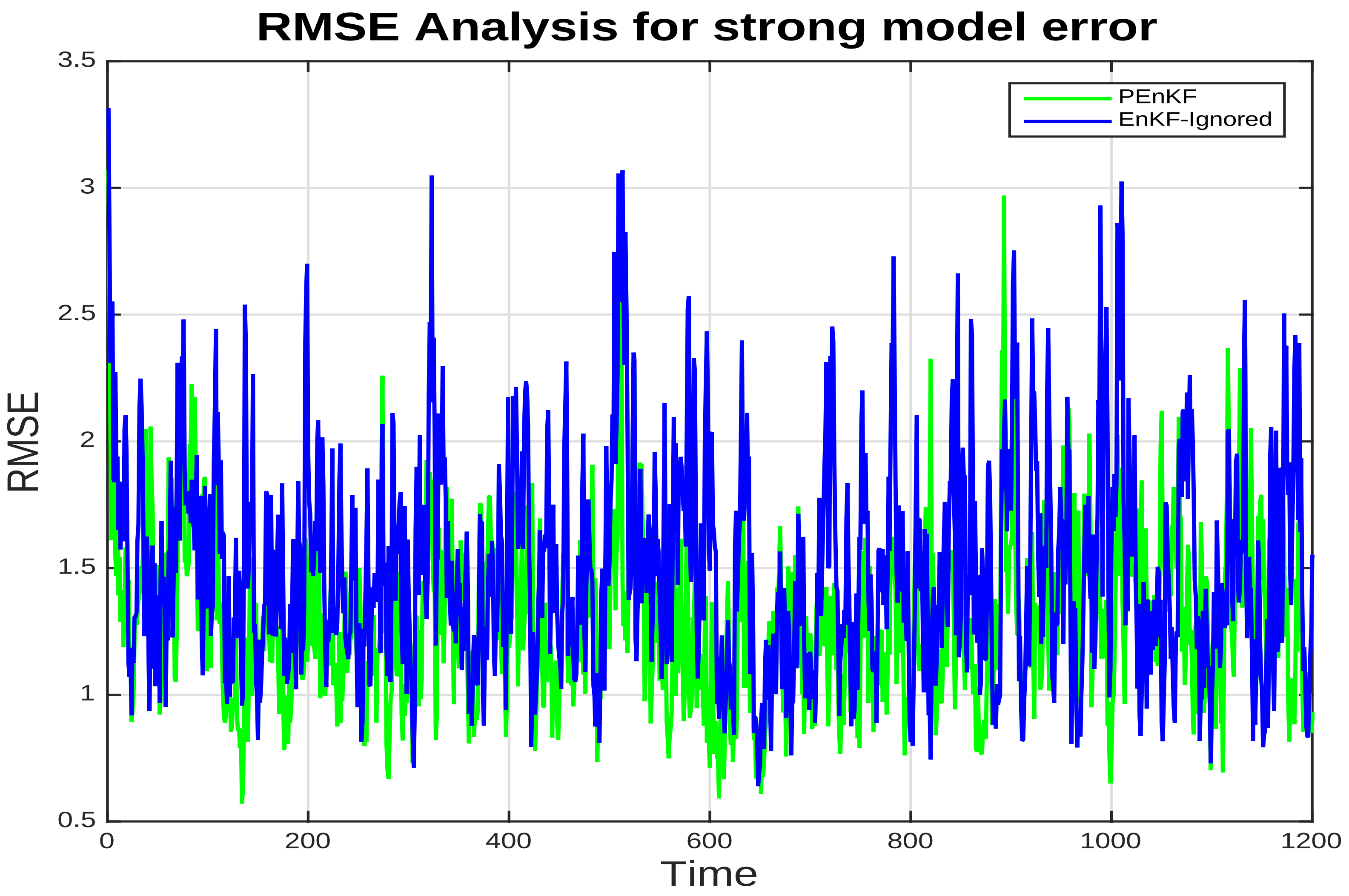








Sensitivity-Model Error



Conclusion and future work

- Adding qualitative information with PEnKF
  - Improve quality of forecast
  - Reduce uncertainty
  - Improves reliability of forecast
- Adding strong model error deteriorates the performance of the proposed DA scheme
- Implementation with some real world model and data set
- To investigate further for some possible improvement if possible


THANK YOU FOR
LISTENING
ANY QUESTIONS?