UC Riverside

Other Recent Work

Title

Mapping and exploitation of signals of opportunity

Permalink

Authors

Kassas, Zaher M, Ph.D.
Morales, Joshua
Khalife, Joe

Publication Date

Title

Mapping and Exploitation of Signals of Opportunity

Permalink

https://escholarship.org/uc/item/9nt0p7cp

Authors

Morales, J.

Khalife, J.

Kassas, Z.

Publication Date

2016-04-22

Mapping and Exploitation of Signals of Opportunity

## Joshua Morales, Joe Khalife, and Zaher M. Kassas

Motivation

Global navigation satellite system (GNSS) is at the heart of autonomous vehicle navigation systems. However, GNSS signals are unreliable due to:

- Severe attenuation in deep urban canyons
- Intentional and/or unintentional jamming
- Spoofing

Approach: COpNav

Collaborative opportunistic navigation aims to exploit signals of opportunity (SOPs) in the environment.
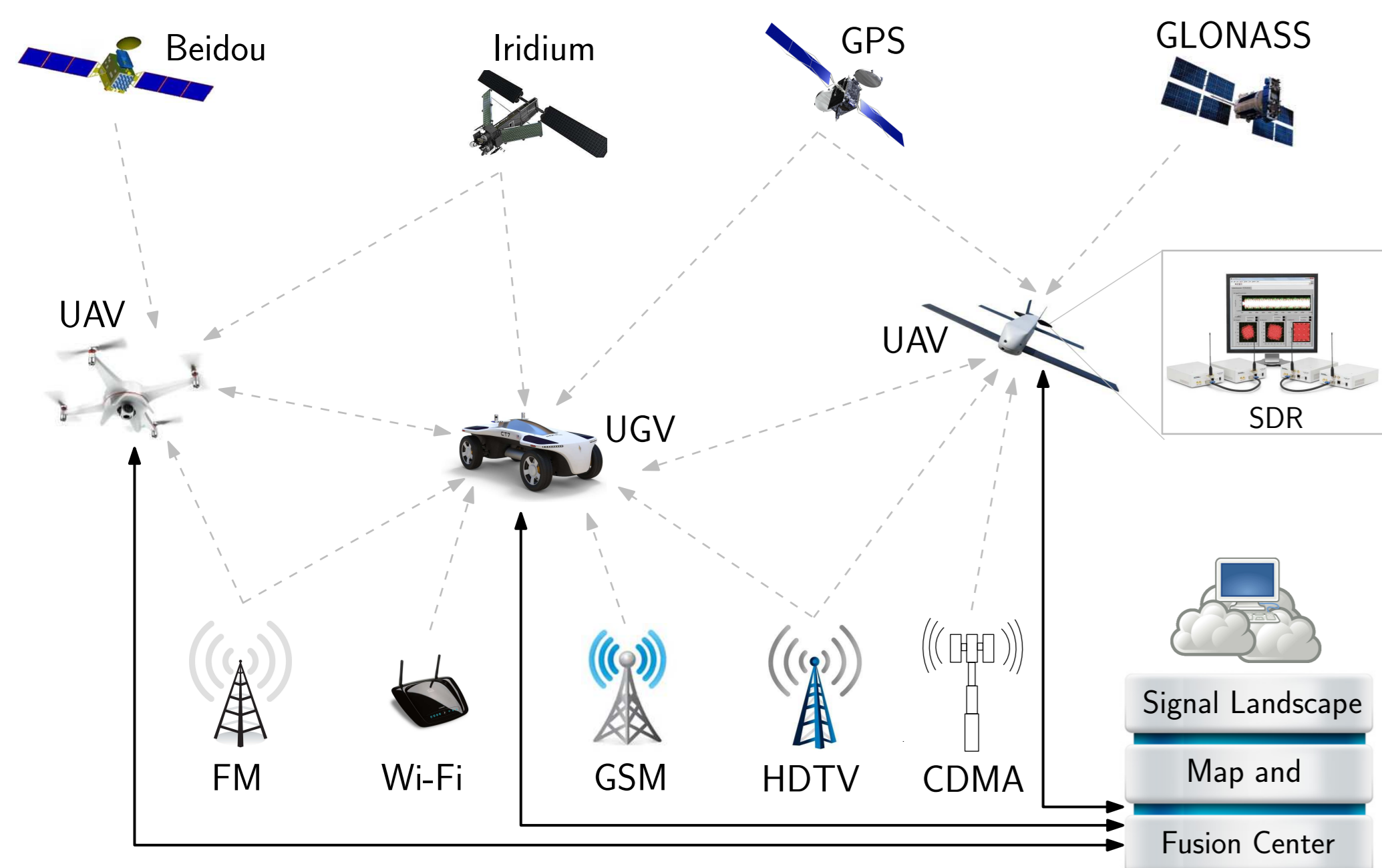
Challenges

- **Unavailability of most SOP emitters' states (position and clock)**
- Less stable clocks than GNSS satellite vehicles
- Unavailability of receiver architectures for navigation observables extraction

Advantages

- **Available from varying geometric configurations**
- **Abundant and free to use**
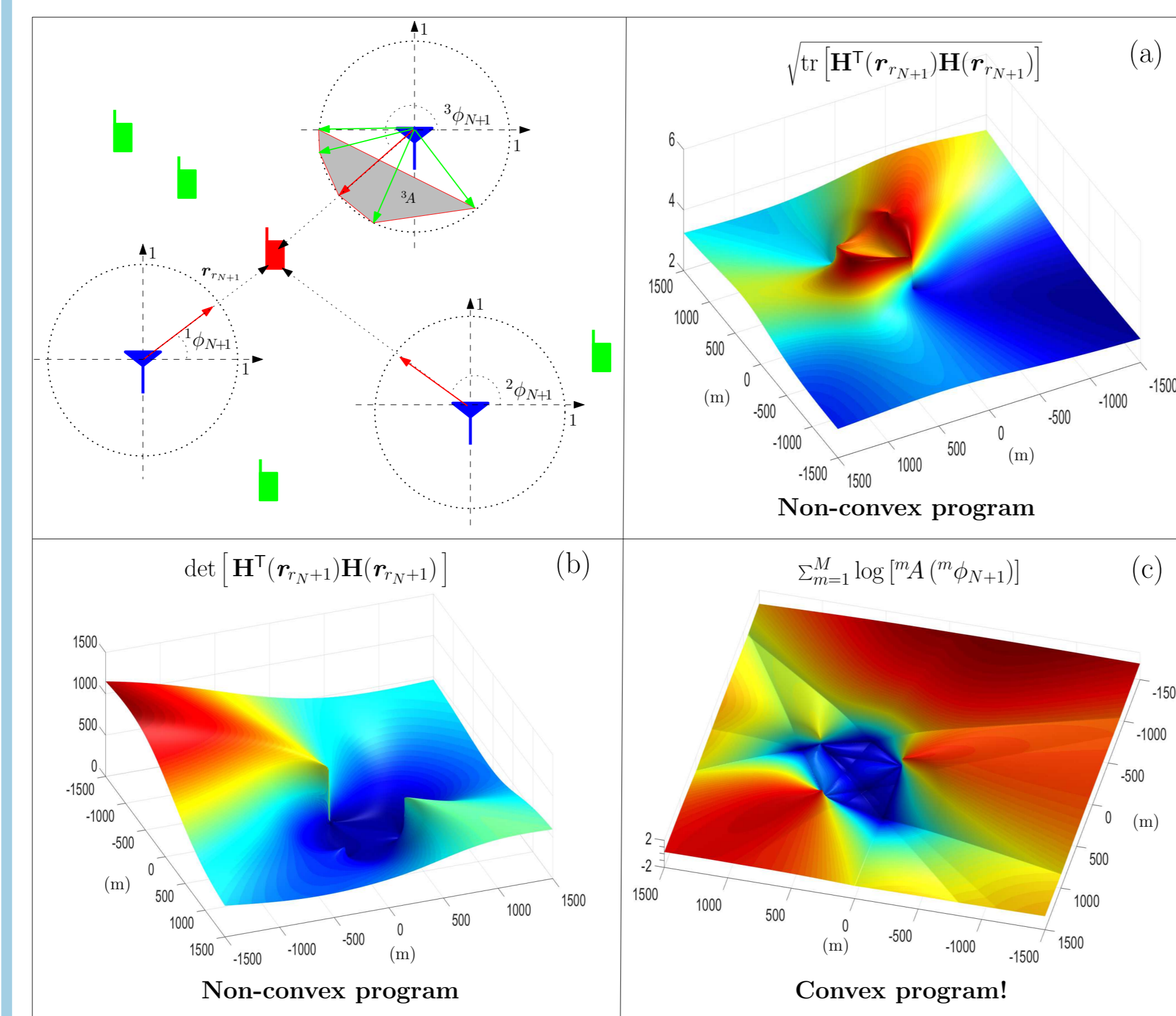- Higher received power compared to GNSS signals

Optimal Receiver Placement

Consider a planar environment comprising M unknown SOPs and N arbitrarily placed receivers with knowledge about their own states. The receivers draw pseudorange observations given by

$$^m z_n = \underbrace{\|\boldsymbol{r}_{r_n} - \boldsymbol{r}_{s_m}\|_2}_{\text{position states}} + c \cdot \underbrace{[\delta t_{r_n} - \delta t_{s_m}]}_{\text{clock states}} + {}^m v_n.$$
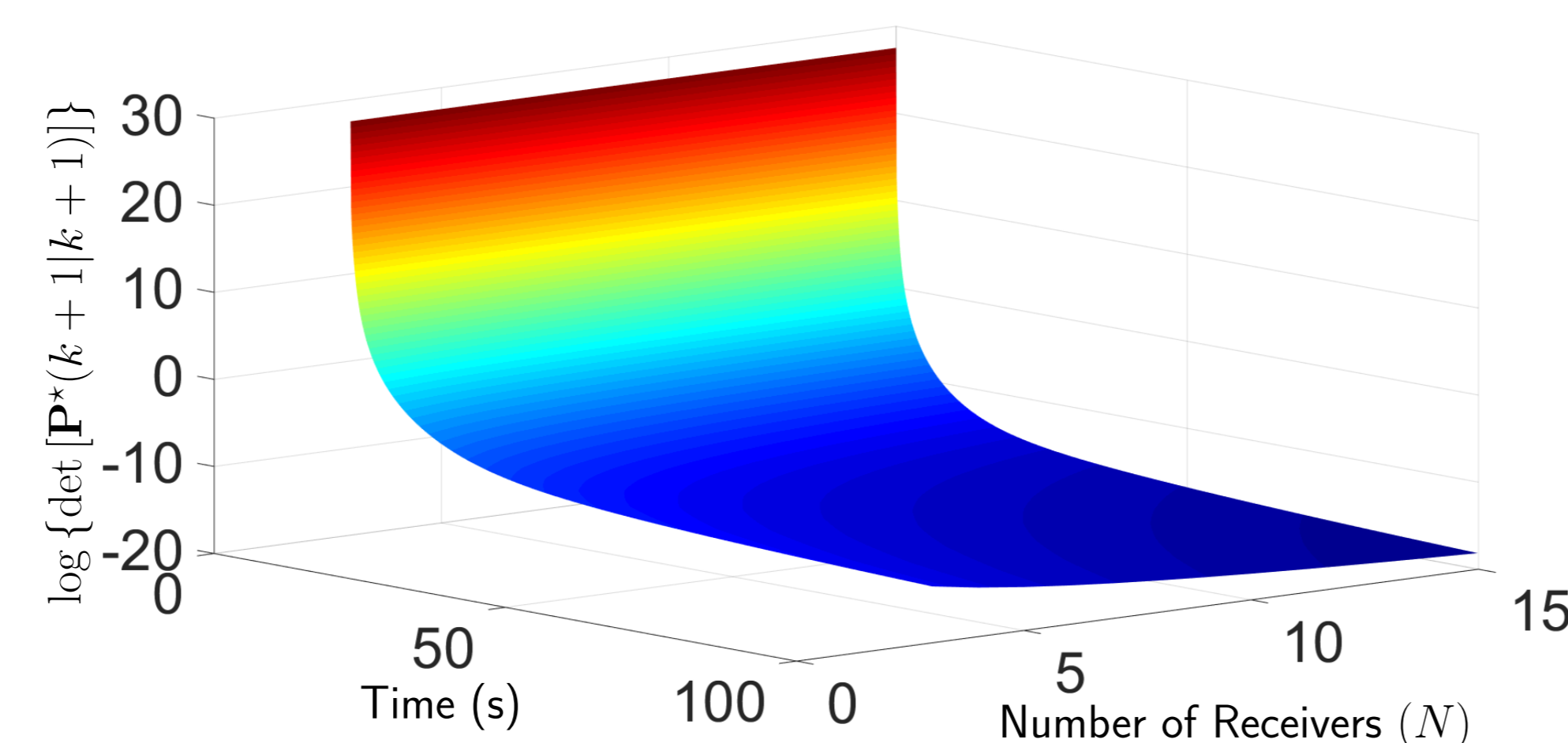
(a) $\displaystyle \underset{\boldsymbol{r}_{r_{N+1}}}{\text{minimize}} \quad \sqrt{\text{tr}\left[\left[\mathbf{H}^{\mathsf{T}}(\boldsymbol{r}_{r_{N+1}})\mathbf{H}(\boldsymbol{r}_{r_{N+1}})\right]^{-1}\right]}$

(b) $\displaystyle \underset{\boldsymbol{r}_{r_{N+1}}}{\text{maximize}} \quad \det\left[\mathbf{H}^{\mathsf{T}}(\boldsymbol{r}_{r_{N+1}})\mathbf{H}(\boldsymbol{r}_{r_{N+1}})\right]$

(c) $\displaystyle \underset{\boldsymbol{r}_{r_{N+1}}}{\text{maximize}} \quad \sum_{m=1}^{M} \log\left[{}^m A\left({}^m \phi_{N+1}\right)\right]$
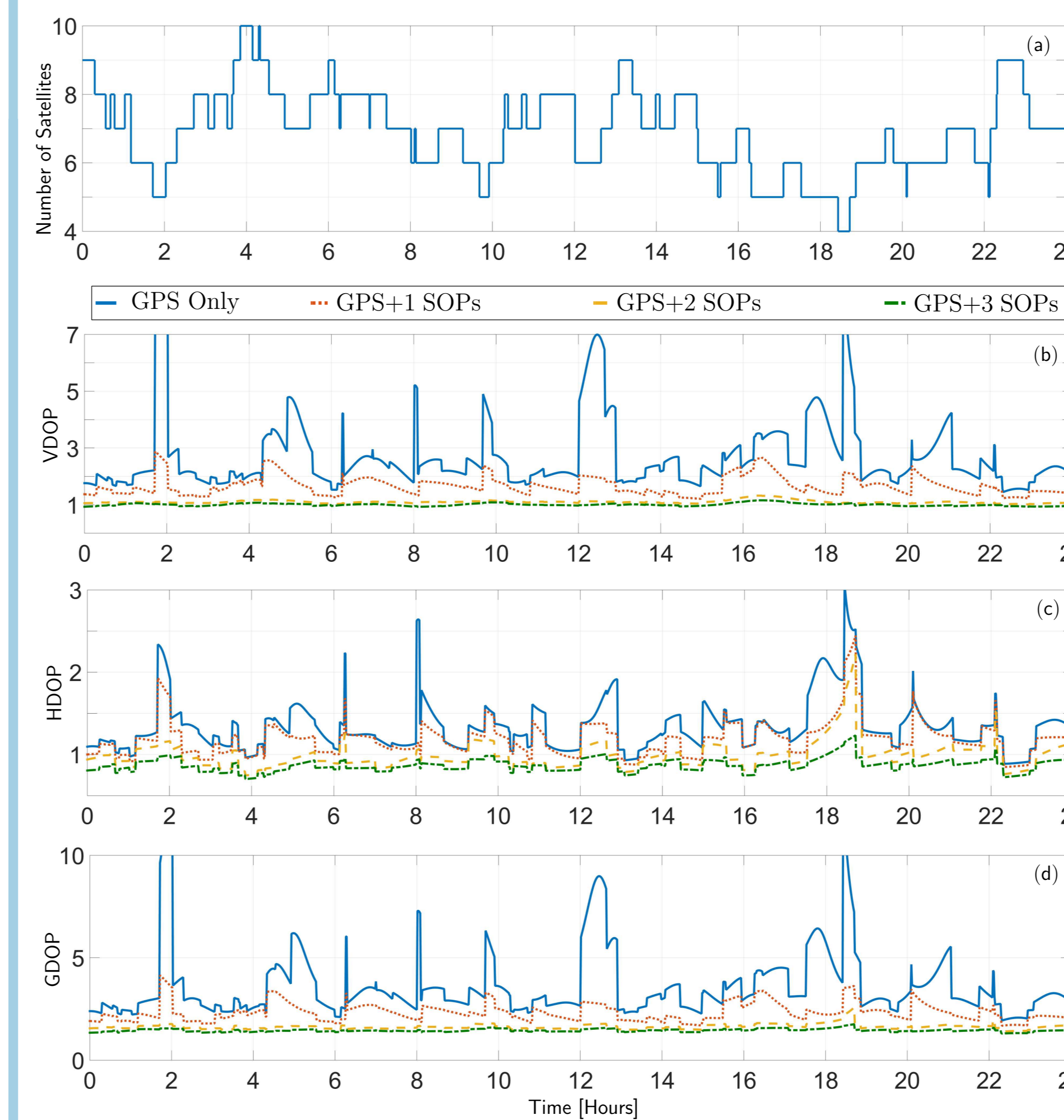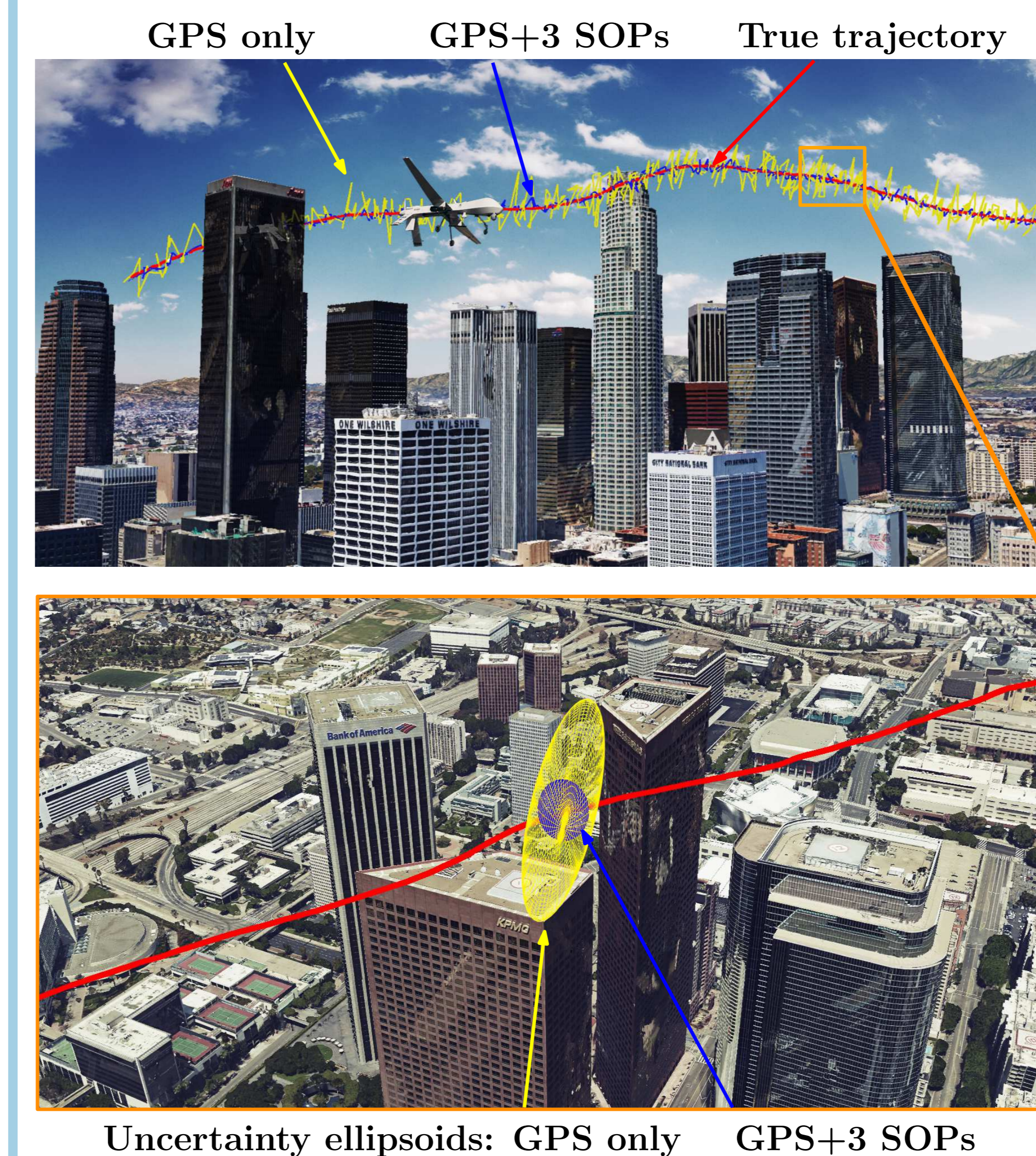

Optimal Emitter Mapping

Exploiting SOPs

1. Accuracy Improvement: GPS+SOPs

2. UAV Simulation Results

GPS only   GPS+3 SOPs   True trajectory

Uncertainty ellipsoids: GPS only   GPS+3 SOPs

Experimental Demo
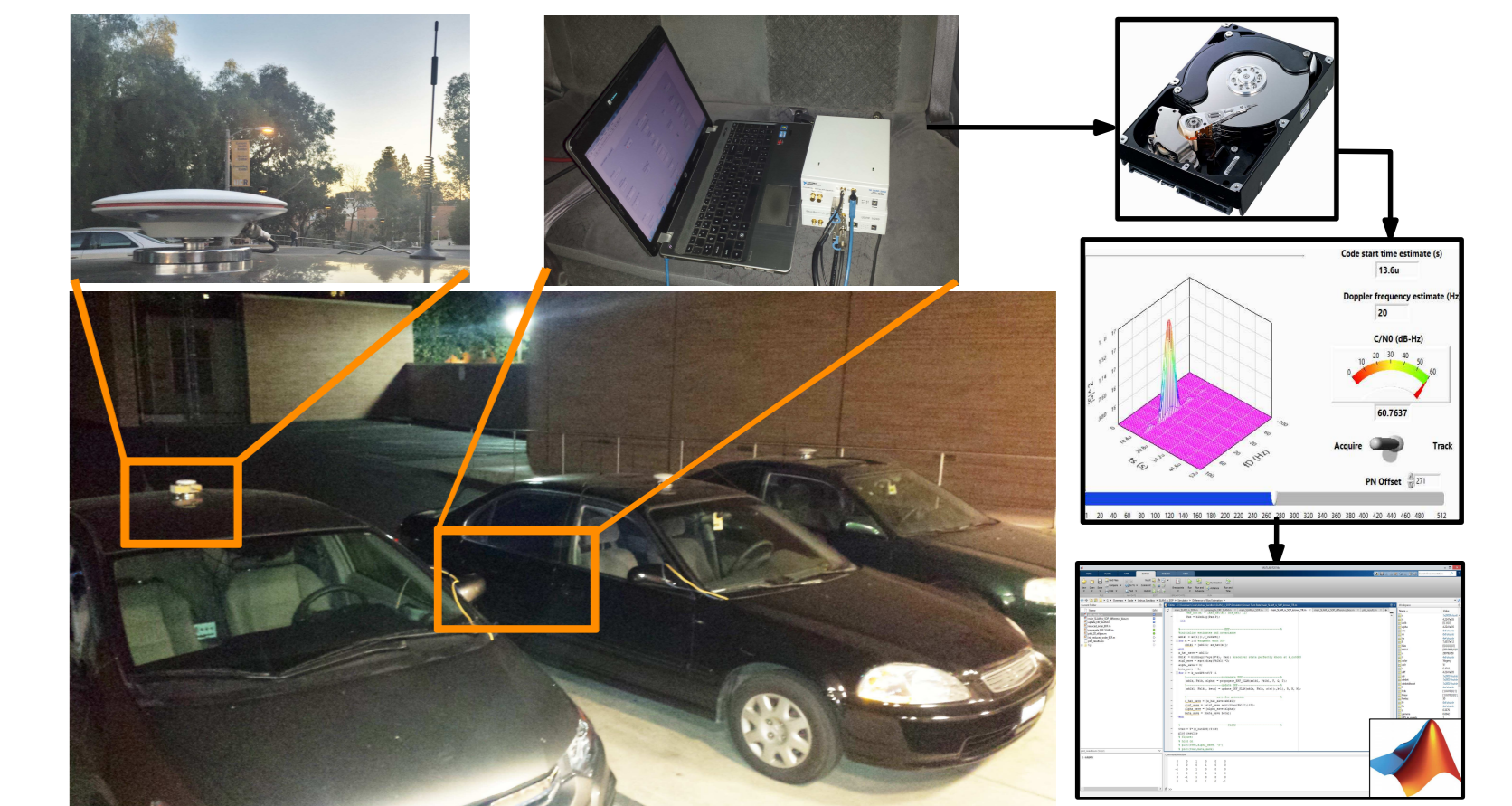
1. Collaborative Mapping of SOP

Receiver trajectories

Initial uncertainty

Emitter localization error: 3.44 m

Final uncertainty
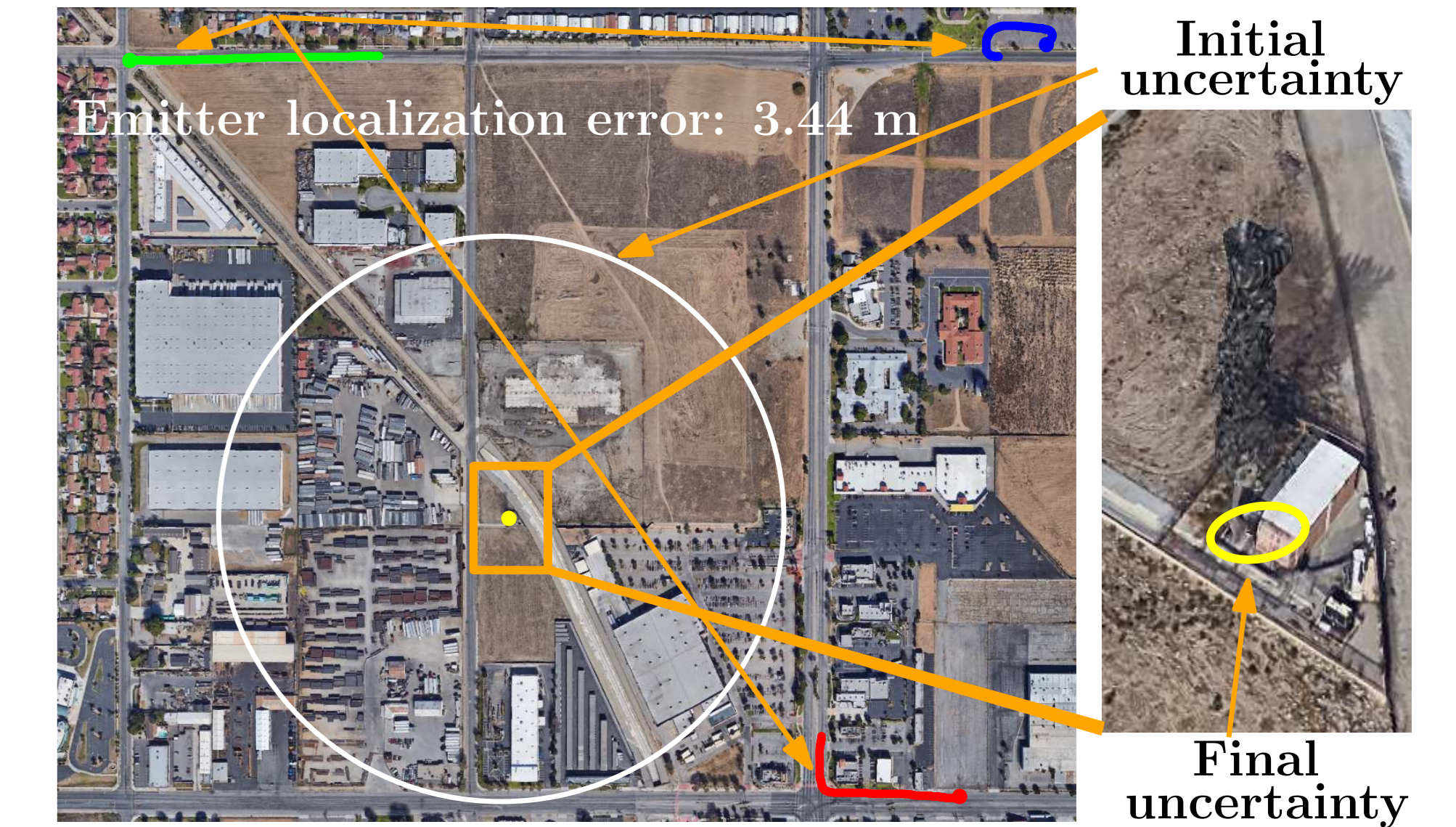
2. Receiver localization improvement
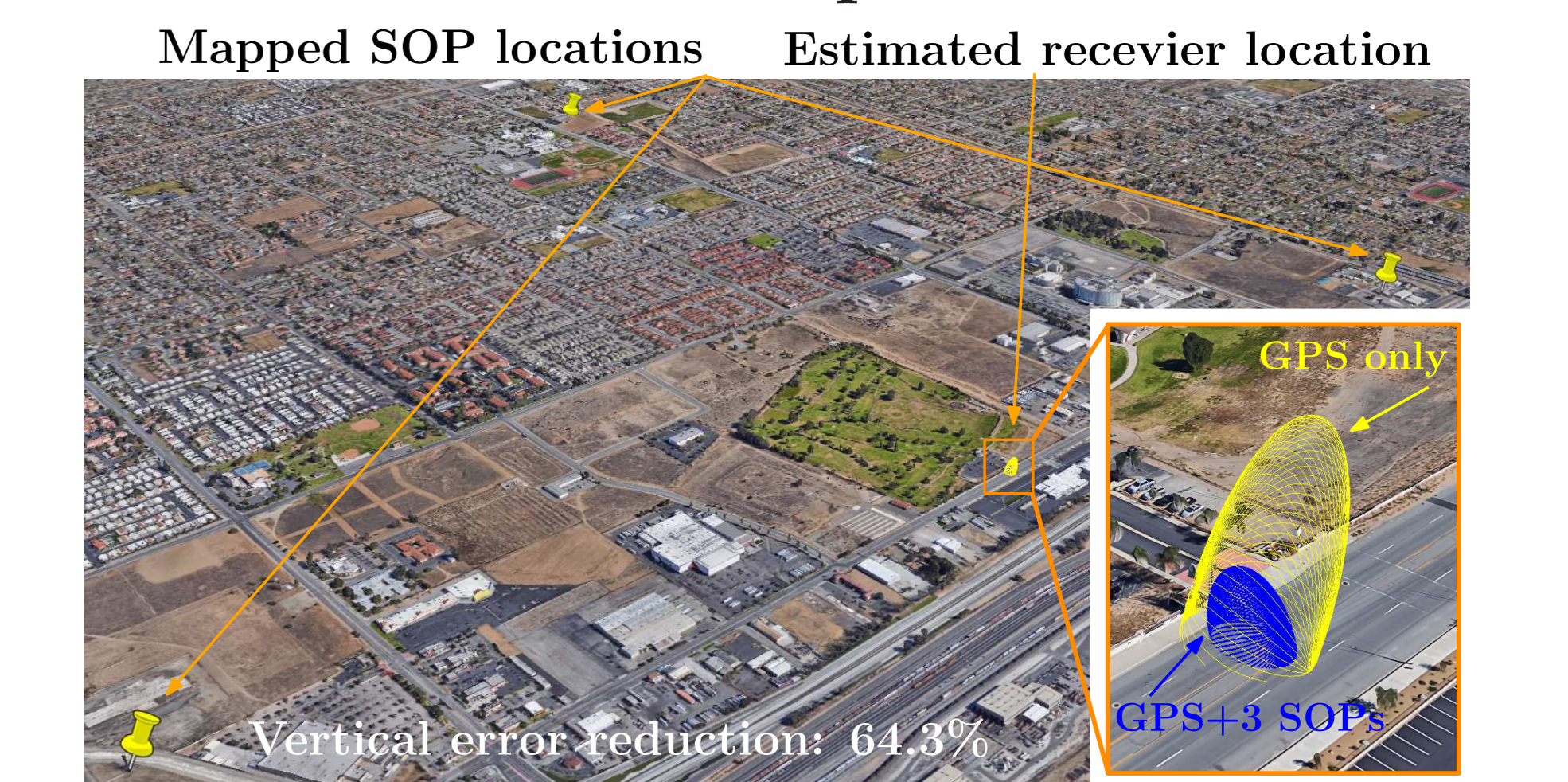
Mapped SOP locations   Estimated receiver location

GPS only

GPS+3 SOP

Vertical error reduction: 64.3%

References

[1] Z. Kassas and T. Humphreys, "Observability analysis of collaborative opportunistic navigation with pseudorange measurements," *IEEE Transactions on Intelligent Transportation Systems*, vol. 15, no. 1, pp. 260–273, February 2014.

[2] J. Khalife, K. Shamaei, and Z. Kassas, "A software-defined receiver architecture for cellular CDMA-based navigation," in *Proceedings of IEEE/ION Position, Location, Navigation Symposium*, April 2016, pp. 816–826.

[3] J. Morales and Z. Kassas, "Optimal receiver placement for collaborative mapping of signals of opportunity," in *Proceedings of ION GNSS Conference*, September 2015, pp. 2362–2368.

[4] J. Morales, J. Khalife, and Z. Kassas, "Opportunity for accuracy," *GPS World Magazine*, vol. 27, no. 3, pp. 22–29, March 2016.

REFERENCES

[1] Z. Kassas and T. Humphreys, "Observability analysis of collaborative opportunistic navigation with pseudorange measurements," *IEEE Transactions on Intelligent Transportation Systems*, vol. 15, no. 1, pp. 260–273, February 2014.

[2] J. Khalife, K. Shamaei, and Z. Kassas, "A software-defined receiver architecture for cellular CDMA-based navigation," in *Proceedings of IEEE/ION Position, Location, and Navigation Symposium*, April 2016, pp. 816–826.

[3] J. Morales and Z. Kassas, "Optimal receiver placement for collaborative mapping of signals of opportunity," in *Proceedings of ION GNSS Conference*, September 2015, pp. 2362–2368.

[4] J. Morales, J. Khalife, and Z. Kassas, "Opportunity for accuracy," *GPS World Magazine*, vol. 27, no. 3, pp. 22–29, March 2016.

[5] Z. Kassas and T. Humphreys, "The price of anarchy in active signal landscape map building," in *Proceedings of IEEE Global Conference on Signal and Information Processing*, December 2013, pp. 165–168.

[6] Z. Kassas, V. Ghadiok, and T. Humphreys, "Adaptive estimation of signals of opportunity," in *Proceedings of ION GNSS Conference*, September 2014, pp. 1679–1689.