Dynamic Light-field Sensing for Distributed Light Pollution Monitoring

Sheng-En Huang, Adnan Abdullah (presenter), Ruo Chen, and Md Jahidul Islam

RoboPI Laboratory, Department of ECE, University of Florida

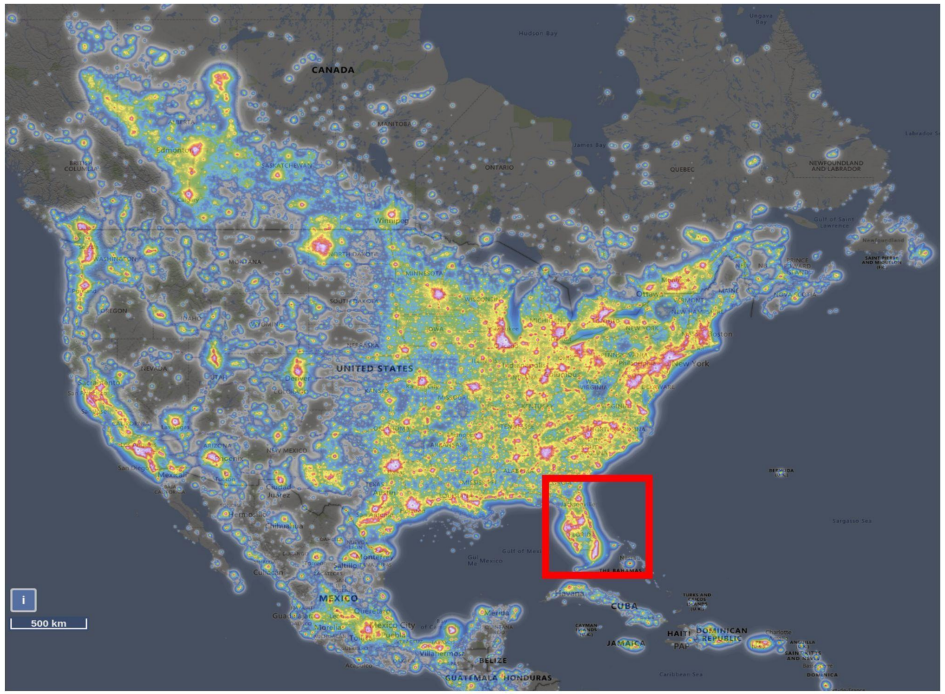


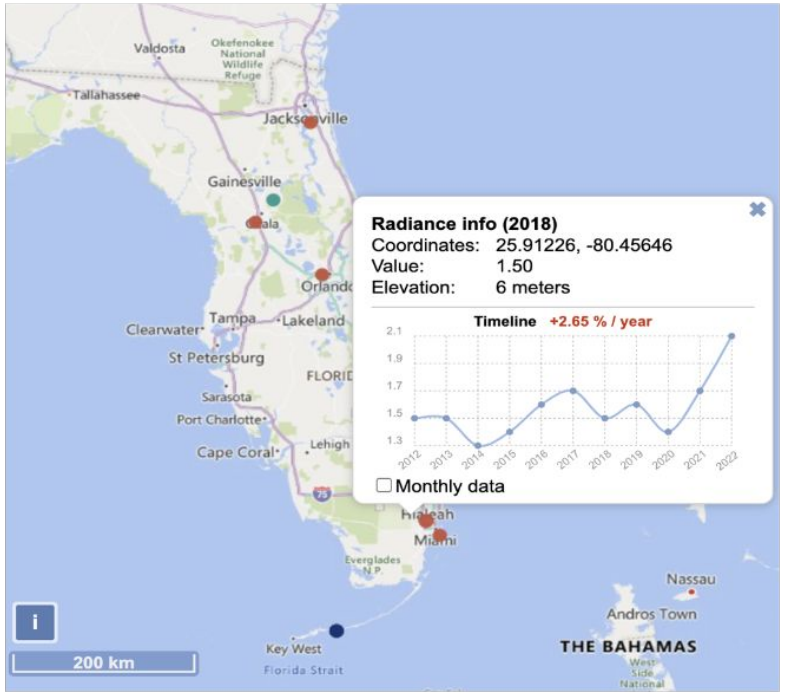




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The Problem: Light Pollution

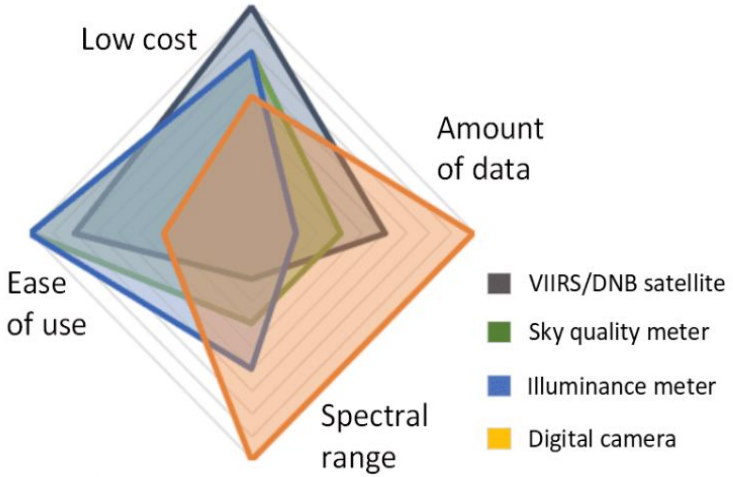




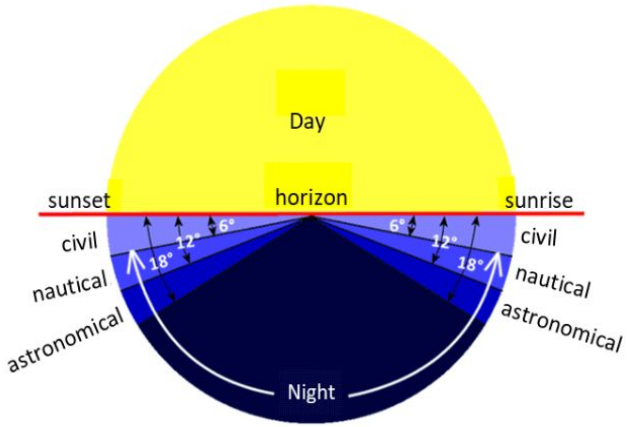
Over 80% of the world and entire U.S. cities and skylines are affected

- **Human health and wellbeing:** Disrupts natural sleep cycles; increases risks for high blood pressure, exhaustion, and depression.
- **Coastal habitat loss:** Affects natal reproductive behavior of sea turtles, birds, and others.
- **Economic impact:** Loss of 7+ Billion usd annually.

Light Pollution Monitoring (LPM)



(a) Subjective analysis of measurements



(b) Twilight types

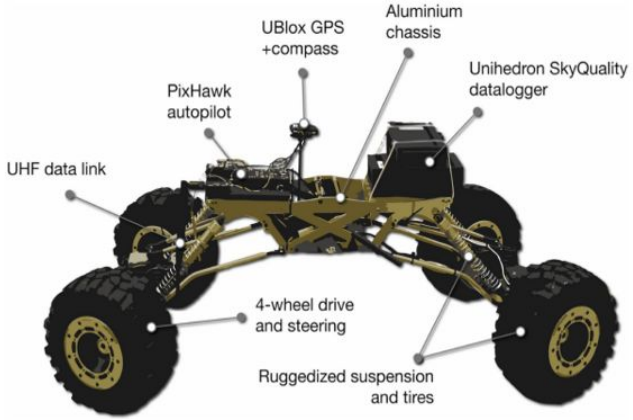

(c) Luminance meter


(d) Sky quality meter (SQM)

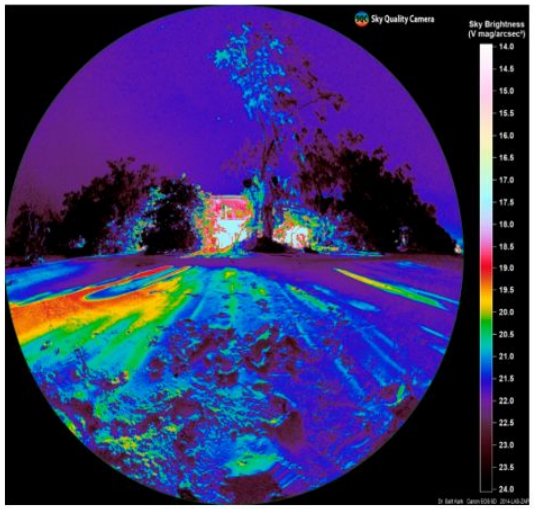
- **Satellite imagery:** VIIRS, DMSP-OLS, AVHRR
  - Poor spatial and intensity resolution
  - Low-sampling rate and latency

- **Single-point ambient sensors:** SQM, Illuminance meter
  - Need manual calibration, static sensing
  - Sensitivity varies depending on the temperature
  - Limited range of observation

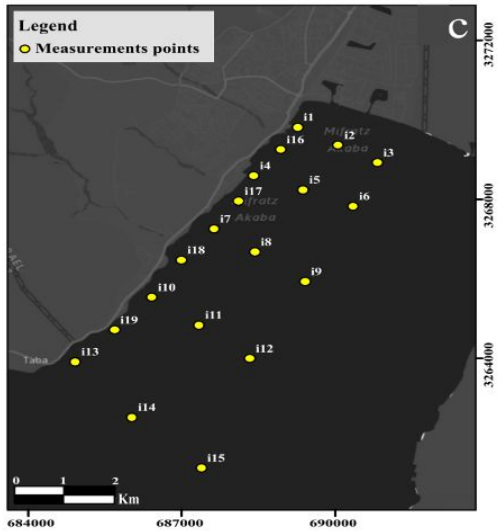
Light-field Surveying and Mapping



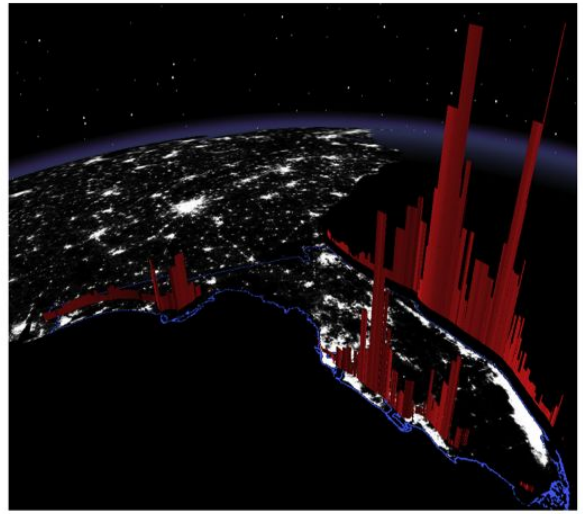
(a) SQM on autonomous rover



(b) Sky quality camera



(c) Situ LPMs in Gulf of Aqaba



(d) Remote sensing via VIIRS

Basic methods:

- ❑ Manual light surveys by humans
- ❑ Dynamic survey via ground rovers
- ❑ Situ measurements in the Gulf region
- ❑ Sky radiance sensing using DSLR

Limitations:

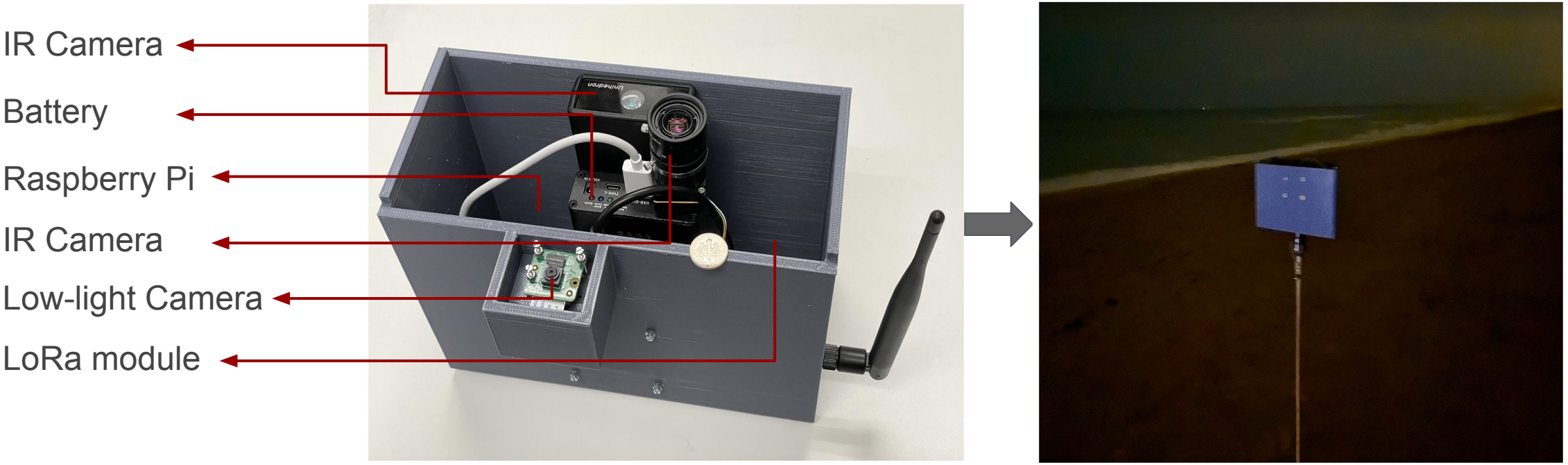
- *Single-point light survey data*
- *Sparse spatial density, low-resolution map*
- *Manual light sensor calibration process*
- *Unscalable, unreliable, not automated*

Missing Technologies



- *Long-term autonomous light-field sensing*
- *Dense 3D light-field mapping and interactive interface*
- *Community action-response tracking mechanism*

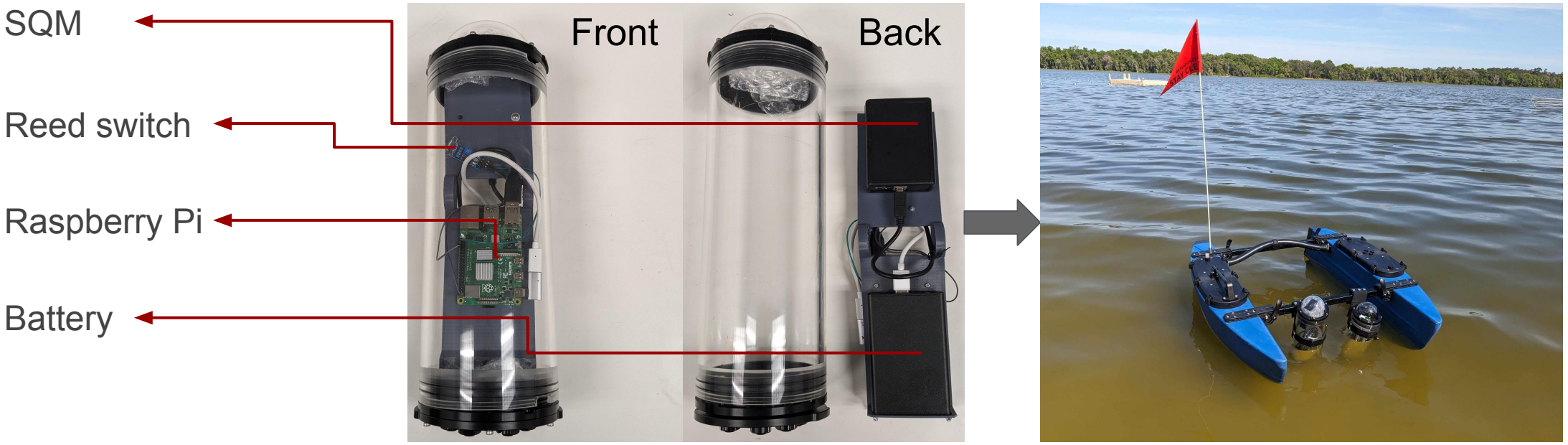
Proposed System: Standalone Sensor Suite



Major Components:

- SQM to measure ambient light intensity
- Low-light cameras for scene radiance
- IR camera for near-ir light fields
- LoRa communication module for remote connectivity
- Low-power integration for long-term standalone operation

Proposed System: Mobile Platform



Integration:

- Watertight enclosure for aquatic operations
- Integrated modular design for portability
- Reed switch to enable contactless triggering
- Transparent doom for SQM viewing window

Novel Features

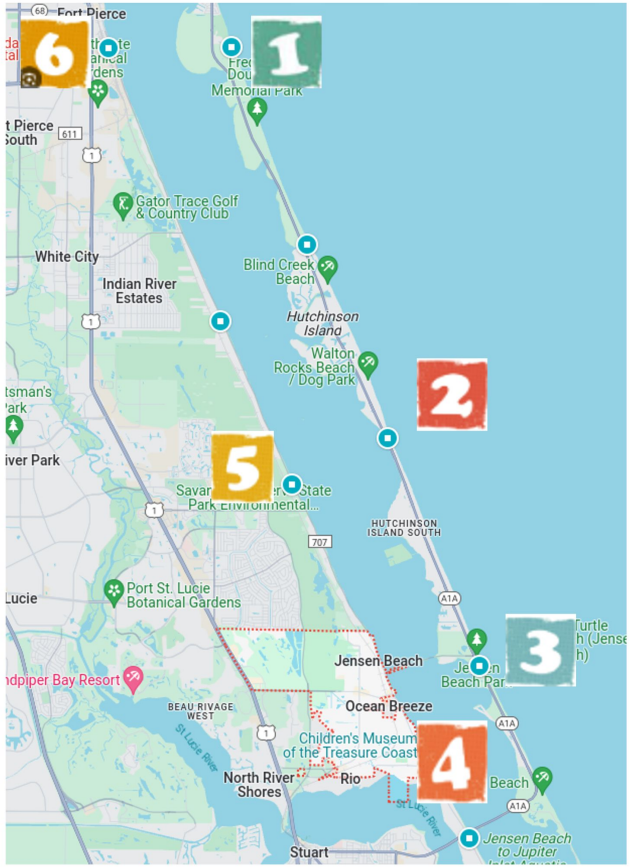


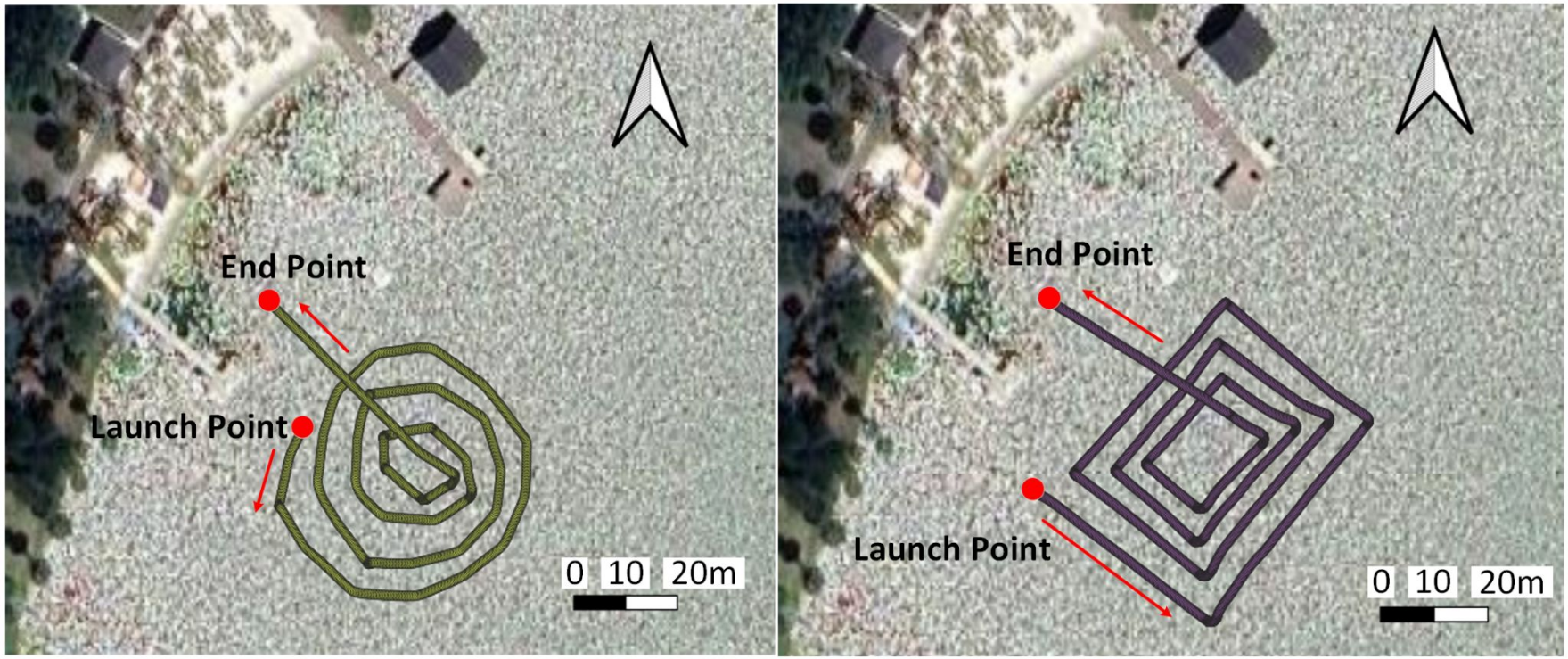


Novel features:

- *Long-term deployability and standalone operation*
- *Dynamic sensing capability without human intervention*
- *High-resolution light-field sensing for dense mapping*
- *Modularized and portable for general-purpose use*

Preliminary Deployment: Mission Planning





Jensen Beach, FL

- Uniformly deployed at *6* locations
- Dual nodes deployment at each place

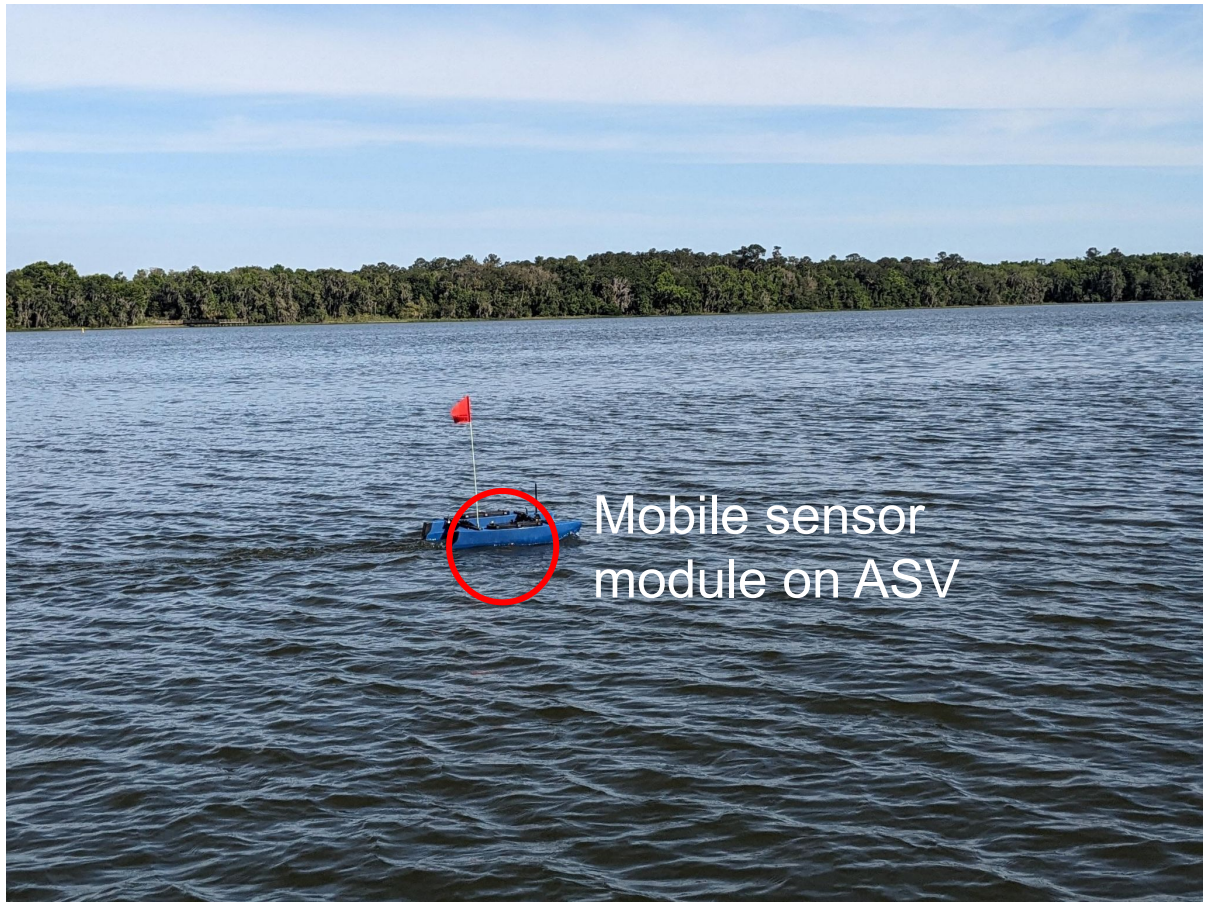
Lake Wauburg, FL

- GPS-guided ASV deployment
- Compact trajectories for high spatial resolution

Preliminary Deployment: Experiment Status

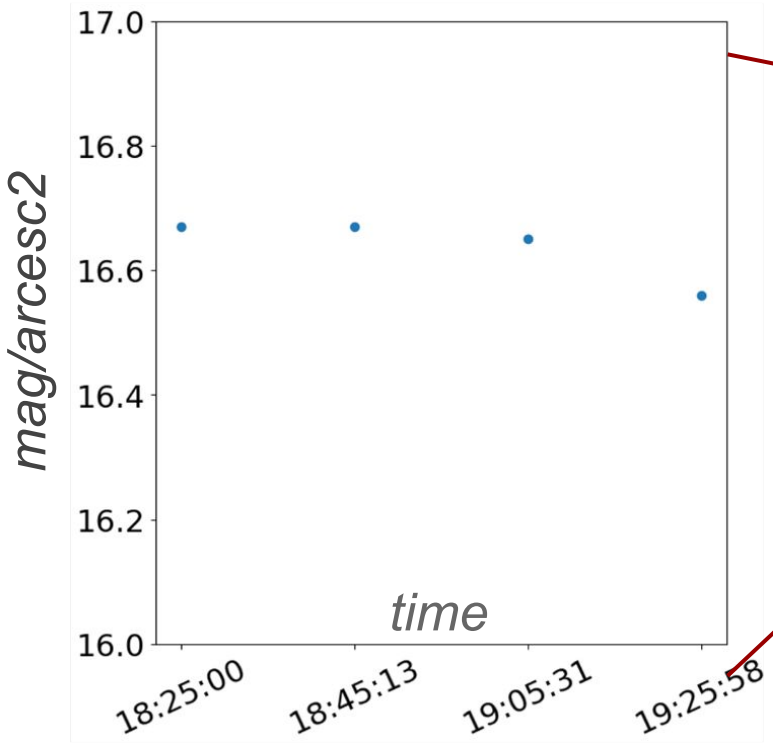


Jensen Beach, FL



Lake Wauburg, FL

Results: Intensity Variations Over Time

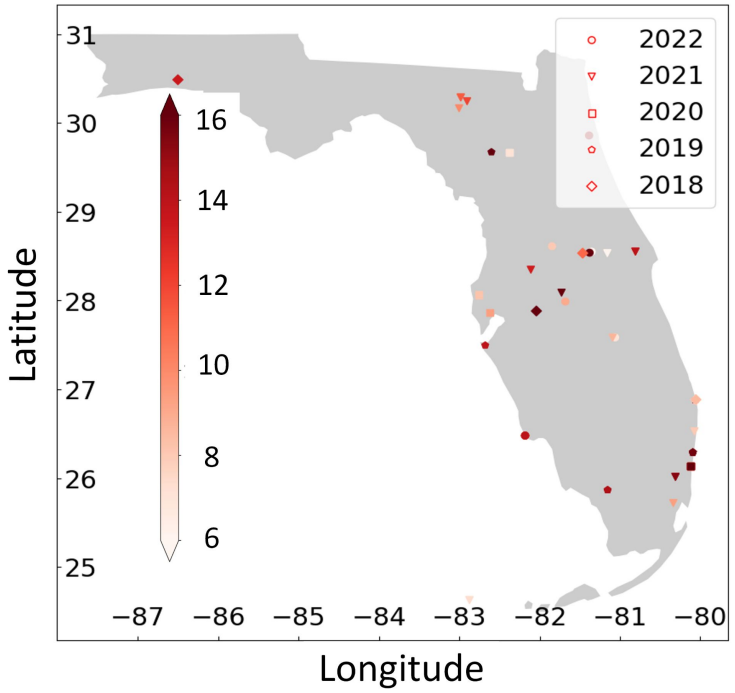


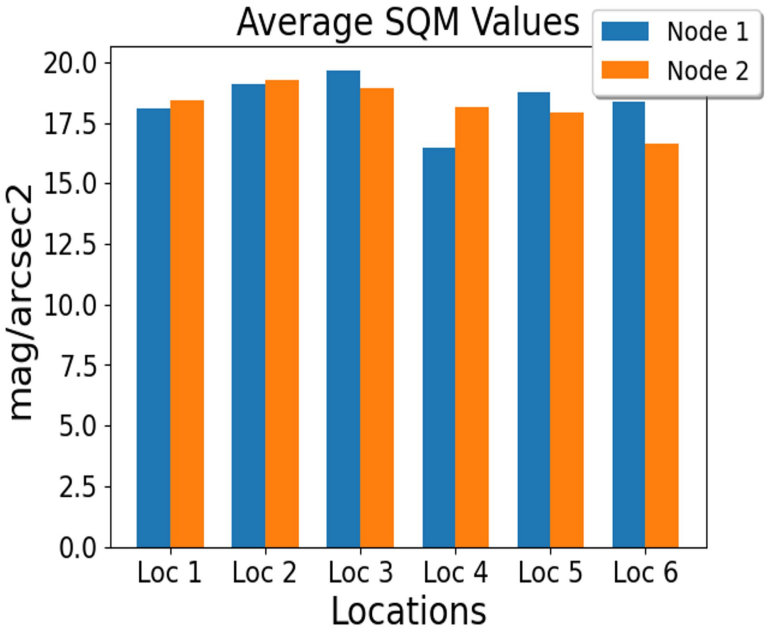


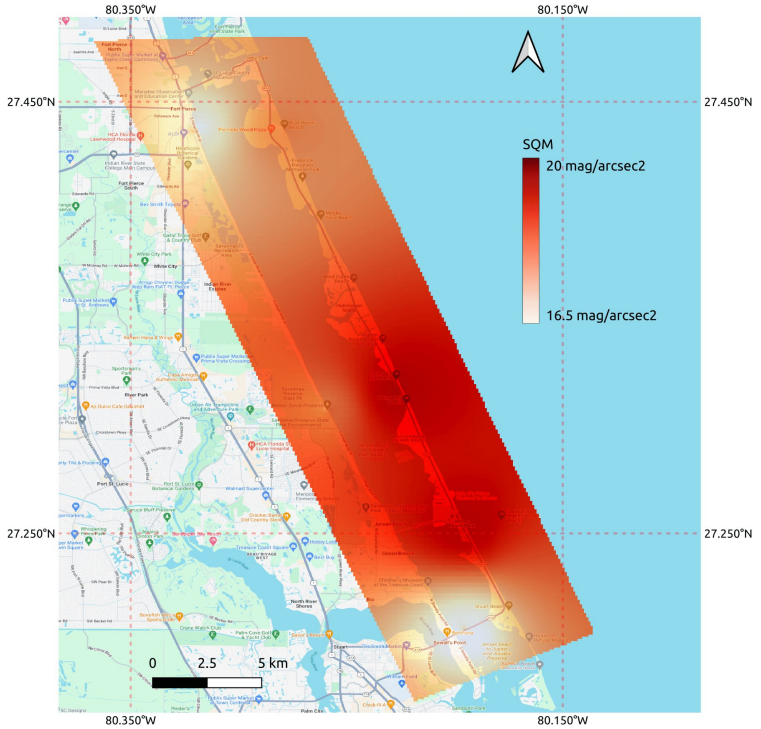
What we found:

- *Much higher spatial and temporal variability in light intensity - compared to what SOTA models suggest*

Results: Analysis of Current and Historical Data







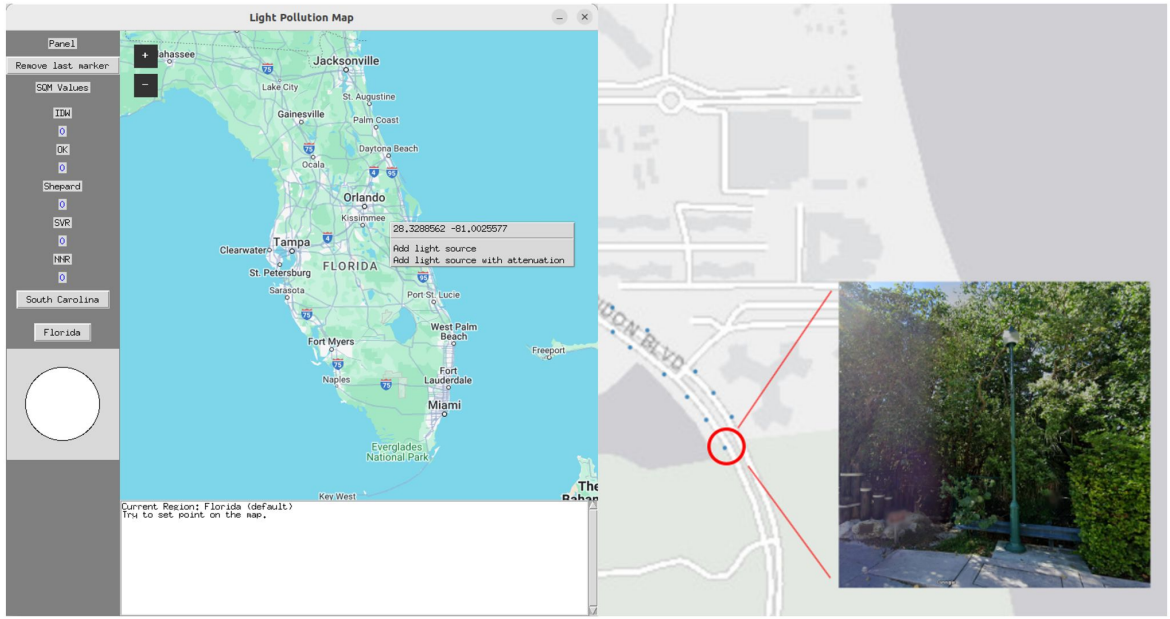
Historical data (Florida):

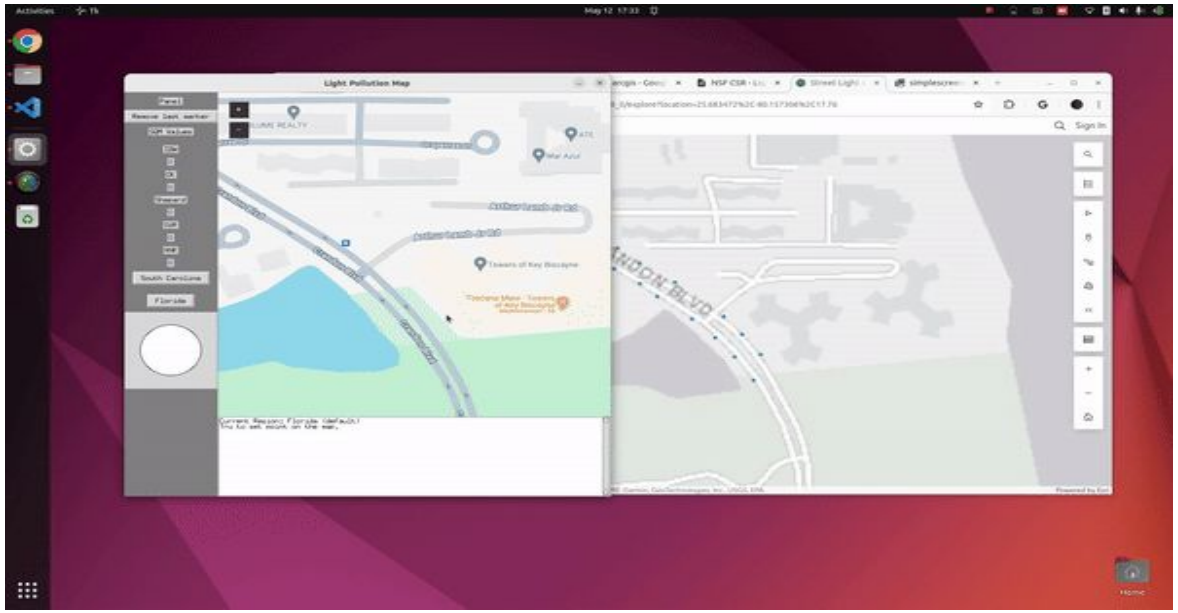
- LP is severe in urban and densely populated areas.
- The level of LP is higher in central and southern FL.

Our Analyses at Jensen Beach (Florida):

- *The changes in LP are significant in residential areas.*
- *The area surrounding Jensen Beach suffers severe LP.*

Conclusion and Future works





Our proposed system:

- ***More Accurate:*** *dynamic deployment and high sampling rates*
- ***Reliable, repeatable and scalable***
- ***Mission programmable:*** *path planning and remote mission controller support*
- ***Dense light-field maps***

Ongoing Work:

- *Distributed sensor network development*
- *Sparse-to-dense interpolation for light fields*
- *Interactive GUI for light map generation*
- *Automated surveying and data integration features in the GUI backend*

Thank You!

Please Visit Our Poster with Any Questions