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A Simulation Toolset for Adaptive Remote Sensing (STARS)

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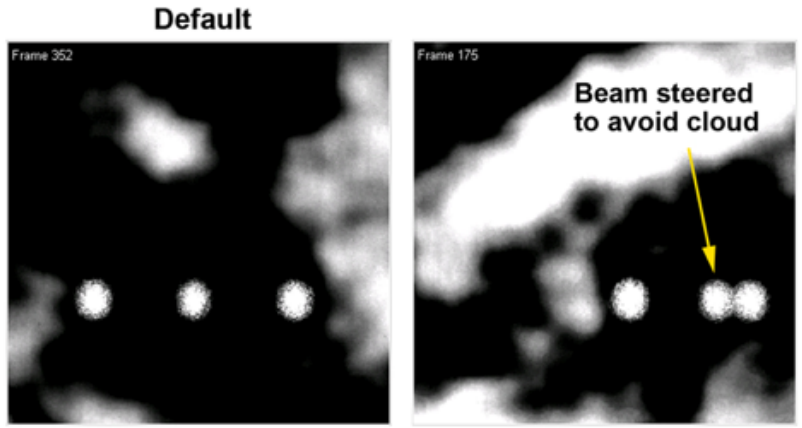
Motivation

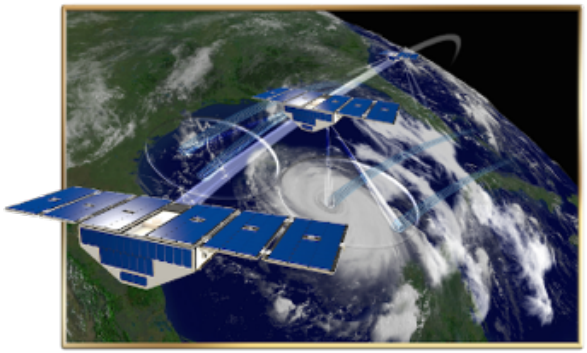
- Future satellite sensing missions will most likely include
  - Adaptive sensors
  - Resource constraints
  - Collaborating constellations
- Next generation modeling and simulation tools are needed
- Therefore AIST funded the Simulation Toolset for Adaptive Remote Sensing

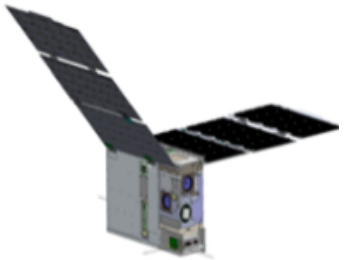


3 beam cloud avoidance demonstration showing default position of beams.

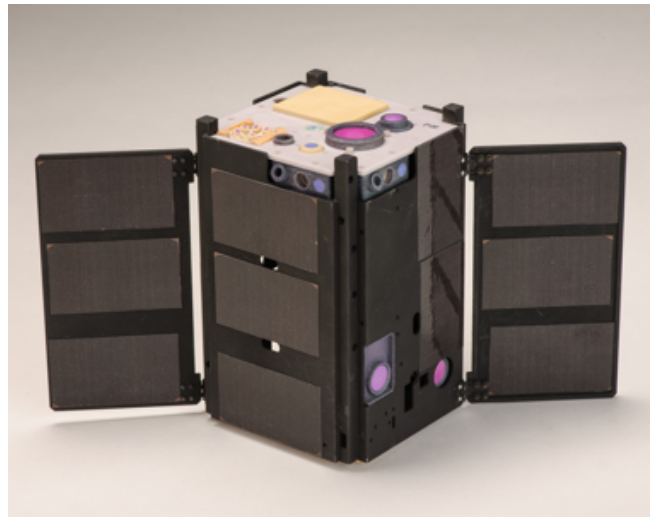
Beams are deflected to closest cloud-free position from their default position.

Ball Aerospace adaptive lidar system steering beams to avoid clouds





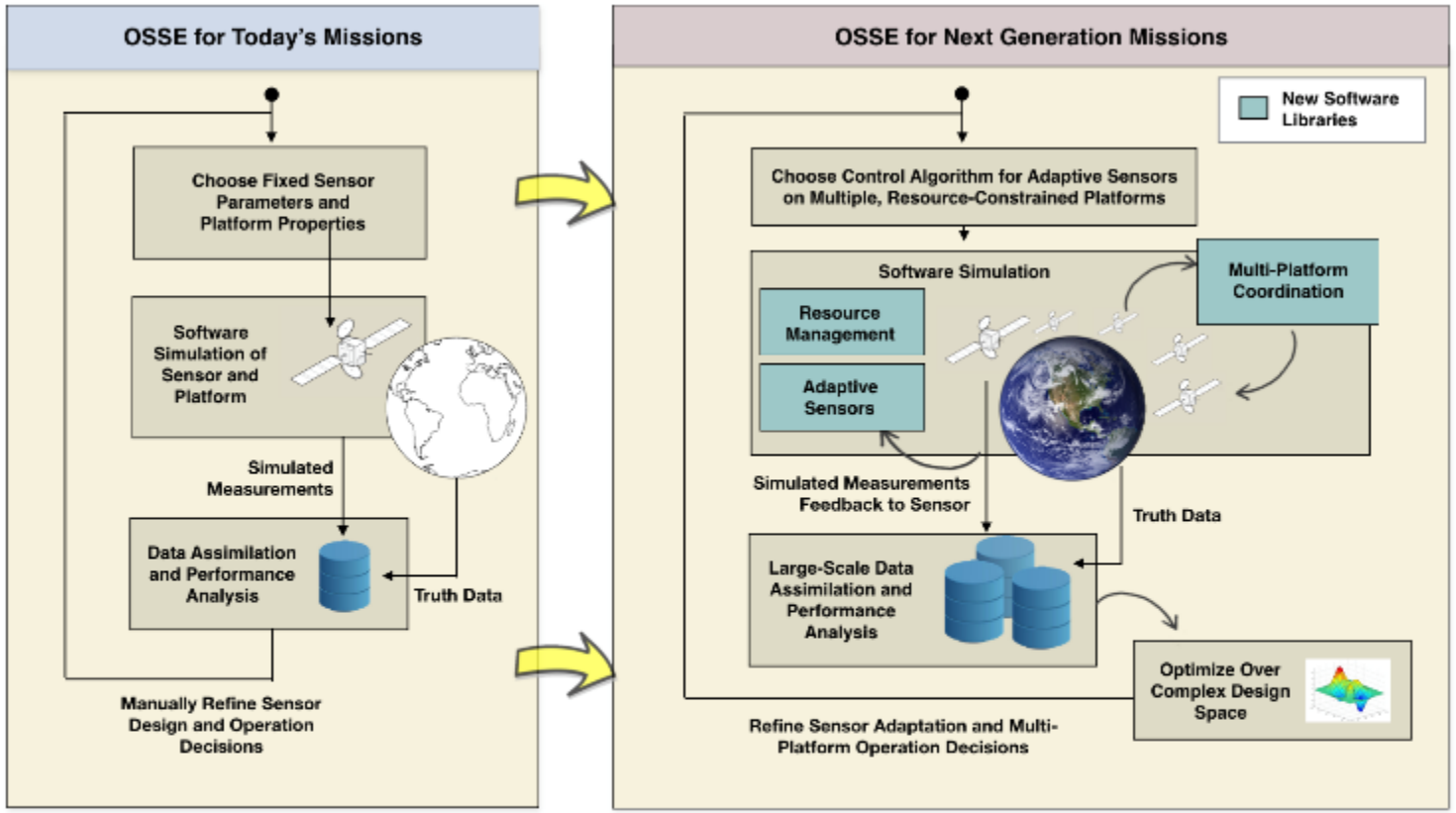
CYGNSS & CubeRRT small sat missions have started to highlight resource constraint challenge for future missions



The Optical Communications and Sensor Demonstration CubeSats will demo high speed links an small sat collaboration

The STARS Concept

- Develop tools to facilitate OSSEs involving adaptive sensors operating under resource constraints in collaborating constellations



OSSE's for NASA's future multi-platform, resource-constrained adaptive sensor instruments will need to leverage software libraries that are specifically designed to address these complex systems

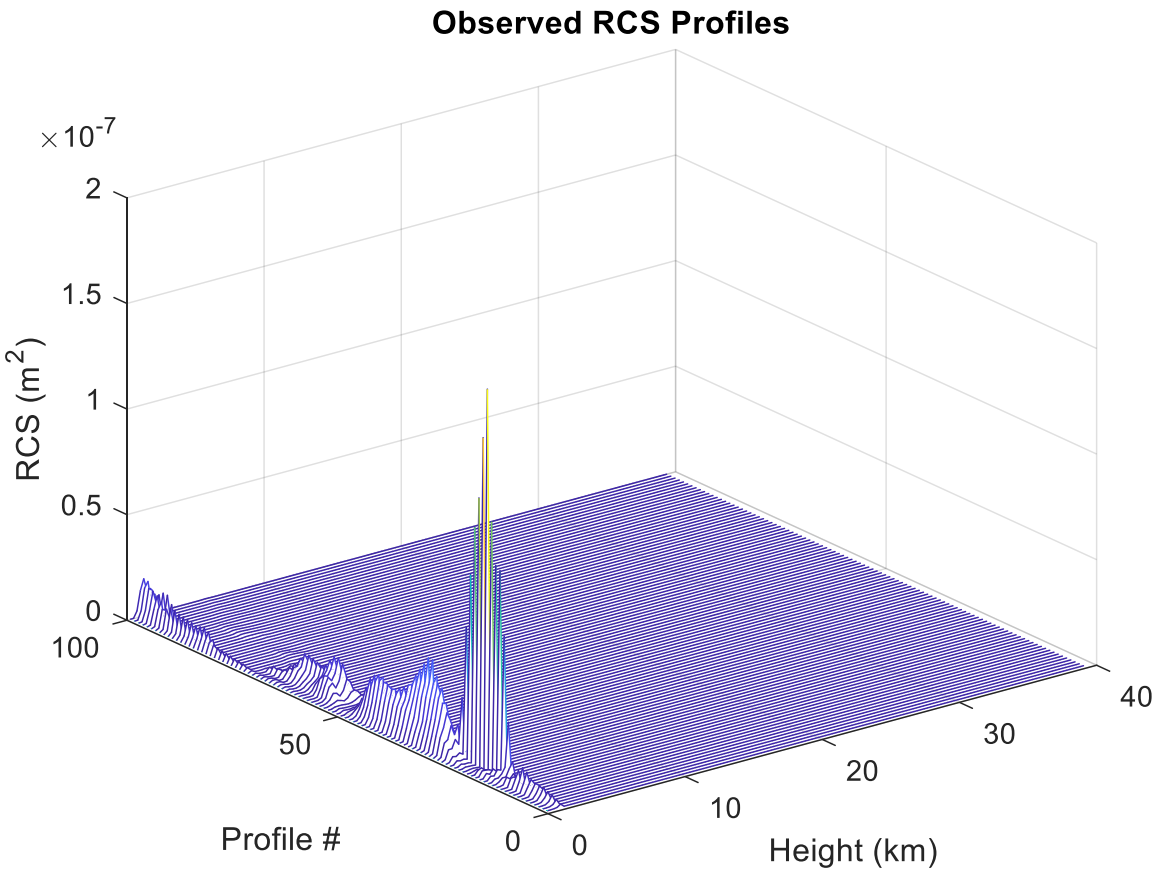
ADAPT: Library

The ADAPT library provides a generalized, abstract interface and structure for the control of adaptive remote sensing systems

- ADAPT library therefore:
  - Provides tools most commonly associated with adaption
  - Provides the a structure for the simulation software
  - Is suitable for use with a variety of task and sensor types
  - Enables a variety of implementations to be modelled

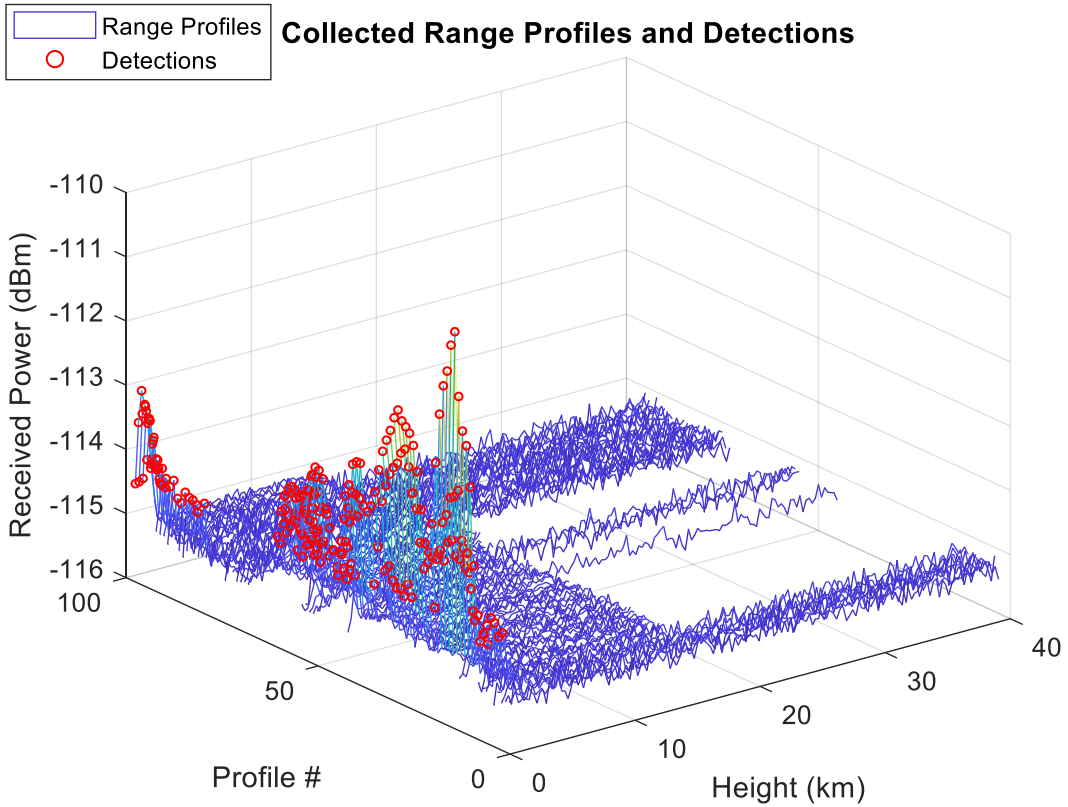
ADAPT: Case Study

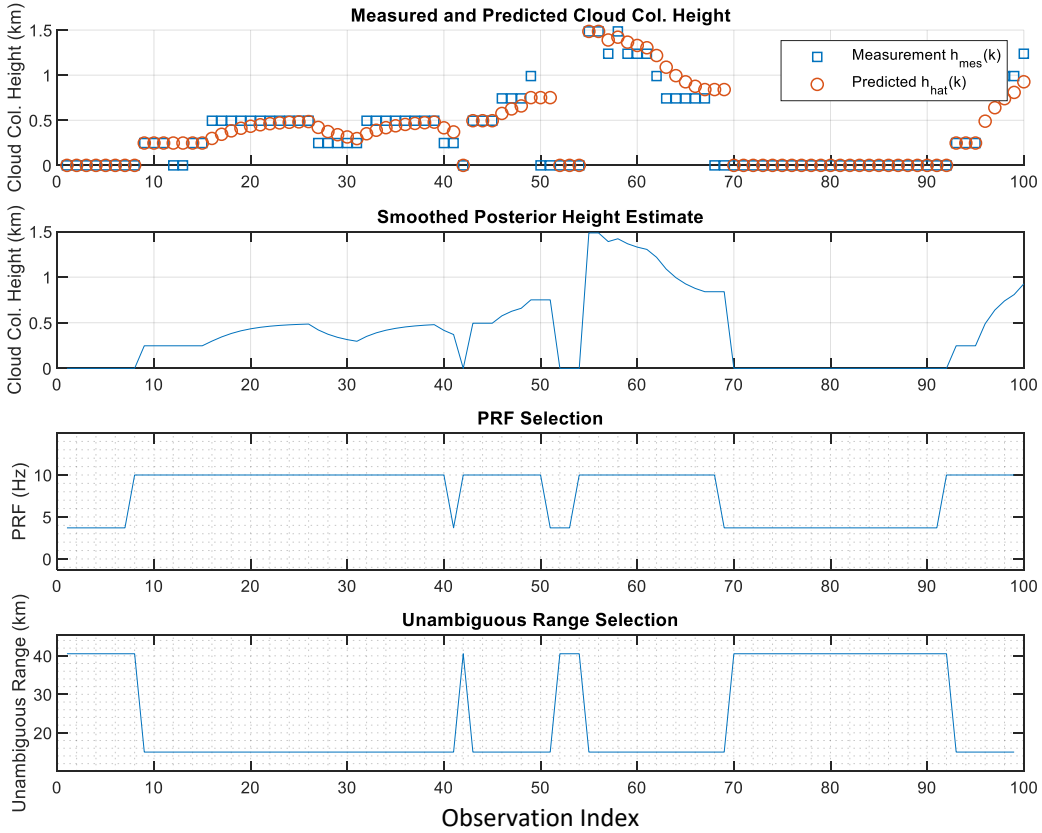
- Cloud profiling radar example
- Parameters from CloudSat
  - 3.3μs rectangular pulse
  - .48s processing interval
  - 1.7kW transmit power
  - 63.1dB gain
- Cloud water content taken from GEOS5
- PRF chosen to match unambiguous range to 1.2 times cloud column height
- PRF chosen via simple cost function with box constraints
- “Perceptions” generated via Kalman filter



ADAPT: Case Study Results

- Clouds reliably detected throughout simulation
- Missed detection can be handled readily
- ADAPT processing structure optimizes PRF values for observed targets





ADAPT: Preliminary Conclusions

- ADAPT can be used to simulate cloud profiling radar
- Matching pulse repetition rates to column height improves measurement quality
  - More pulses to integrate—improves signal-to-noise
  - Greater unambiguous Doppler range will be available
- Cost function can be tuned emphasize particular outcomes
- Next Steps: include velocity/Doppler
  - Have preliminary version of this already

MANAGE: Library

The MANAGE library provides a generalized, abstract interface and structure for the management of platform resources

- MANAGE library therefore:
  - Generalizes the concepts from ADAPT to apply at platform level
  - Provides platform resource models and cost functions to assess value of remote sensing operations
  - Models the link between the sensor and the platform
  - Facilitates autonomous decision making by the platform to manage resources

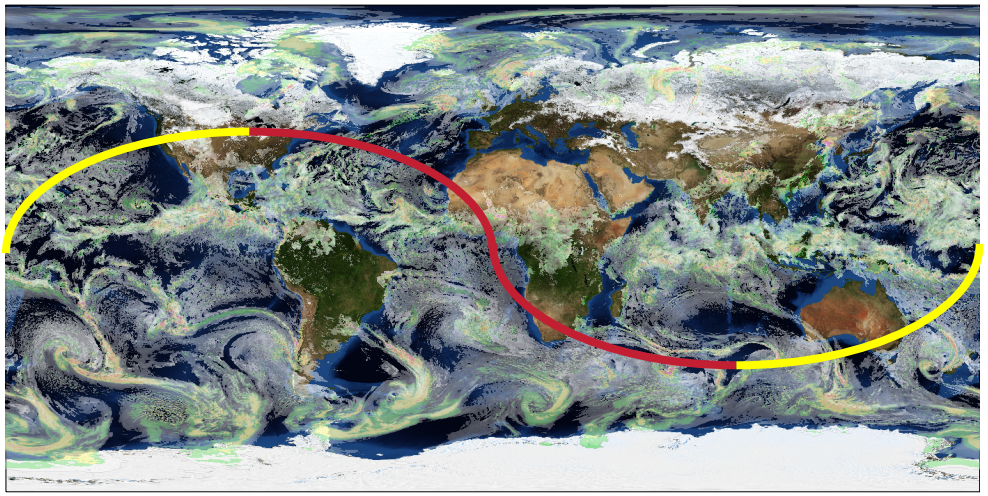
MANAGE: Case Study

- **Goal:** Efficient use power resources in an example remote sensing mission

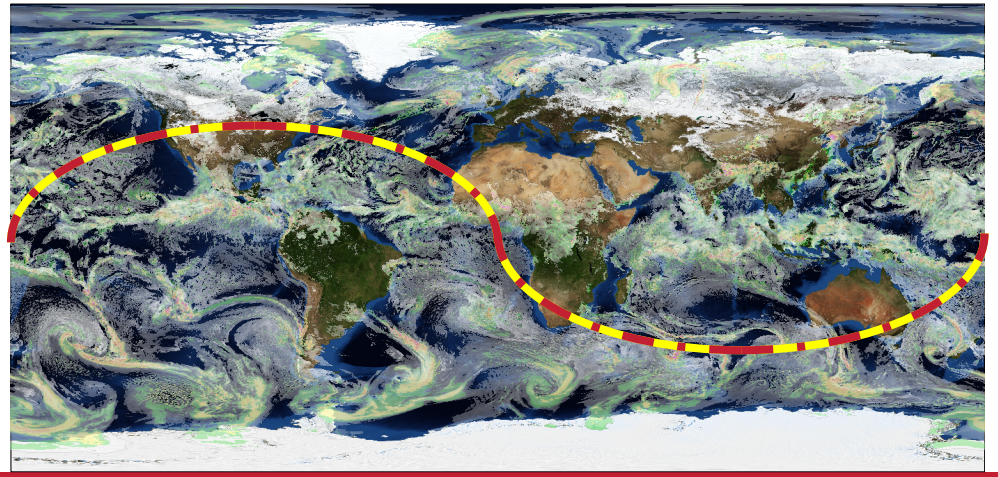
- Baseline Case
  - Orbit duration: 5400 s
  - Number of orbits: 10
  - Duty cycle: 33.33%

- Proposed Adaptive Algorithm
  - Orbit duration: 5400 s
  - Number of orbits: 10
  - Depth of discharge limit: 70.0% max. energy
  - Probability threshold: 0.25

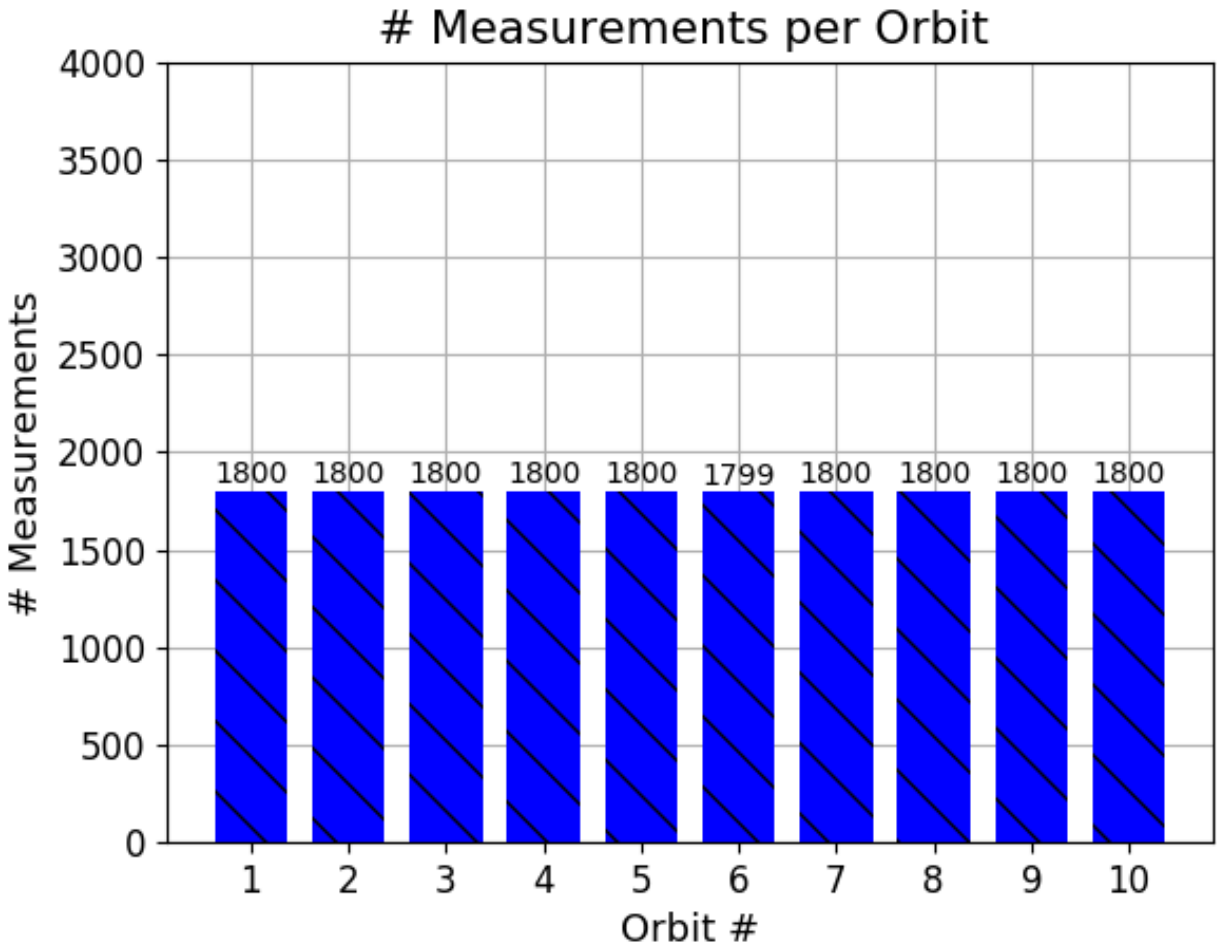
Non Optimized Measurements

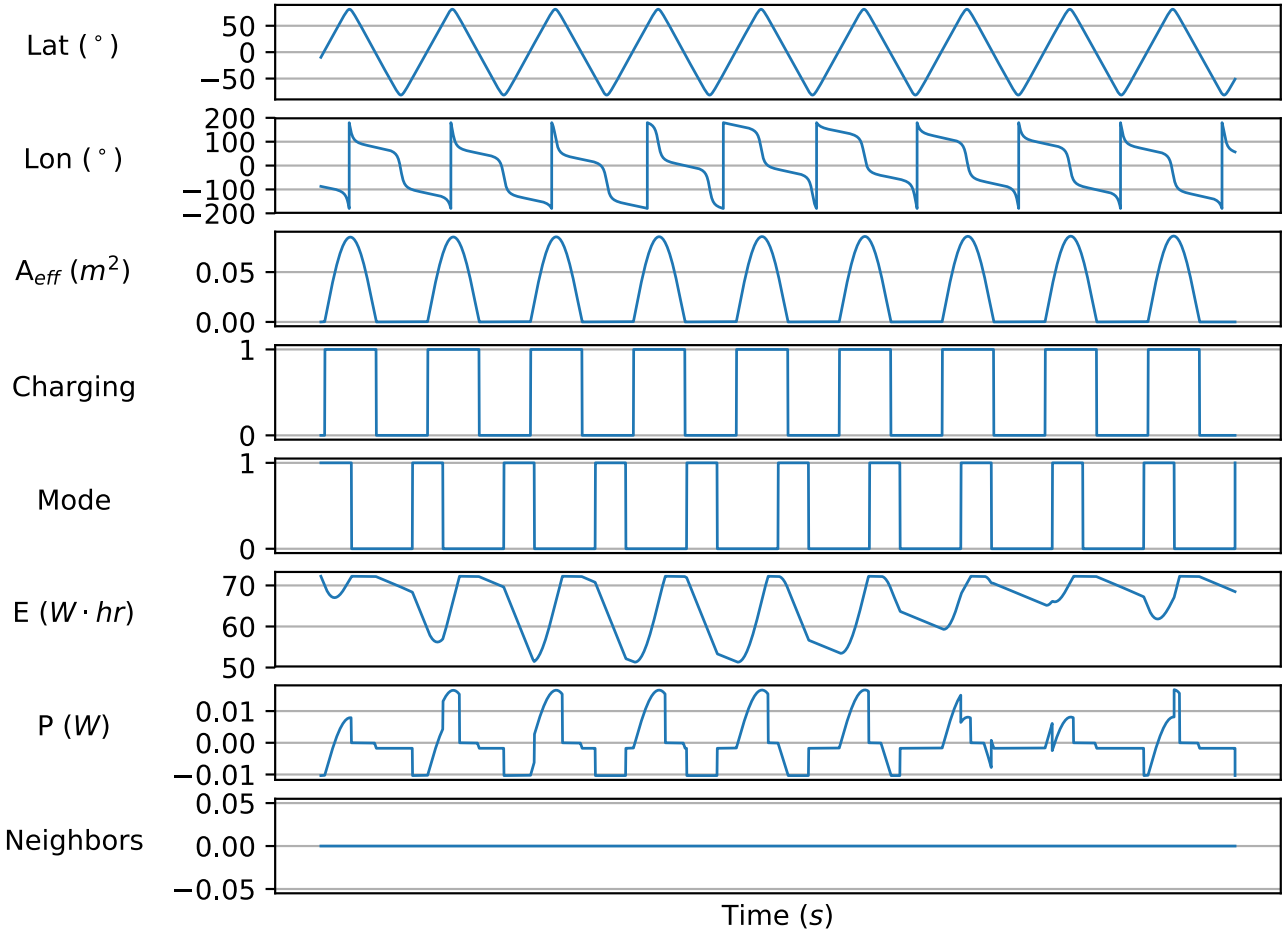


Optimized Measurements

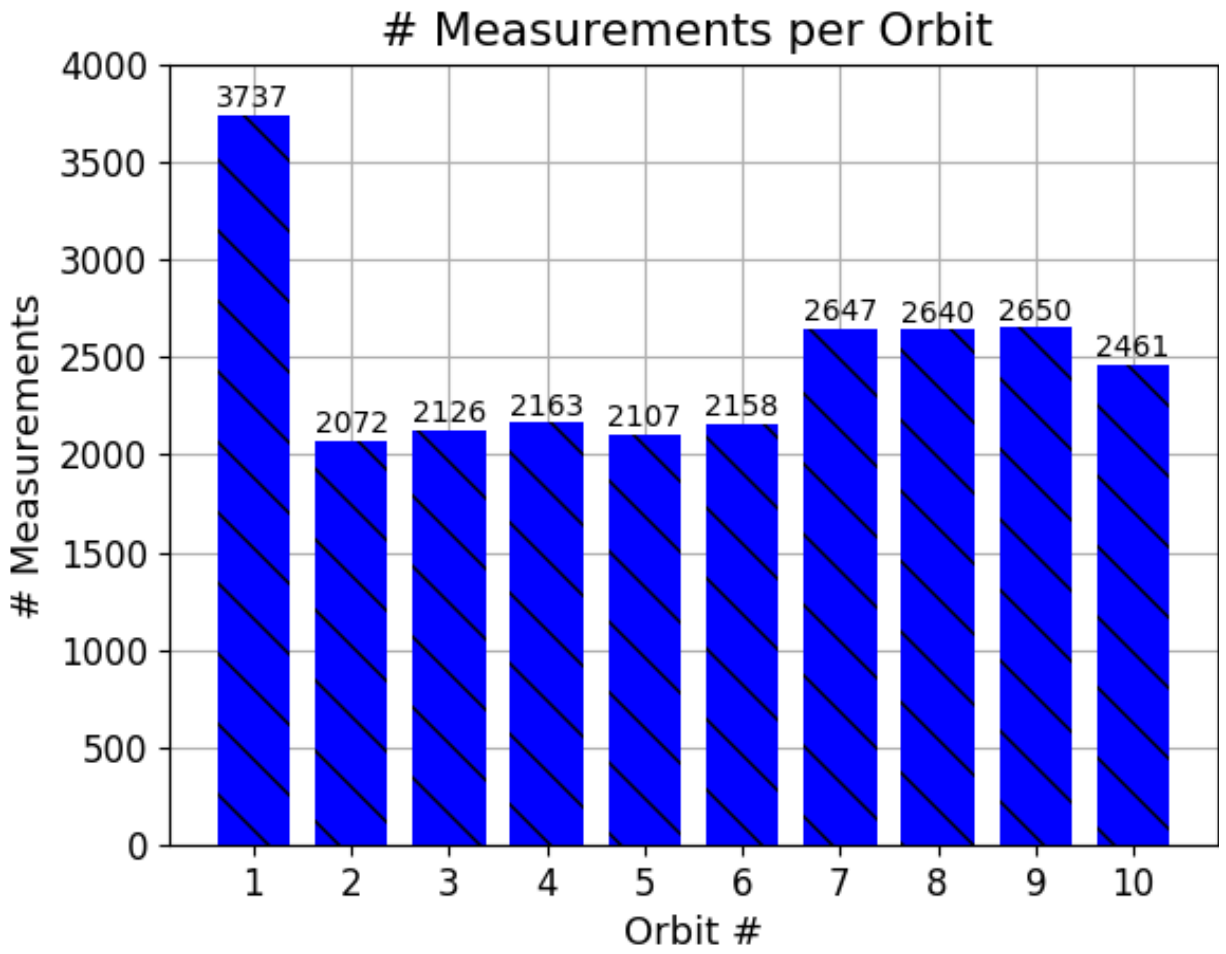


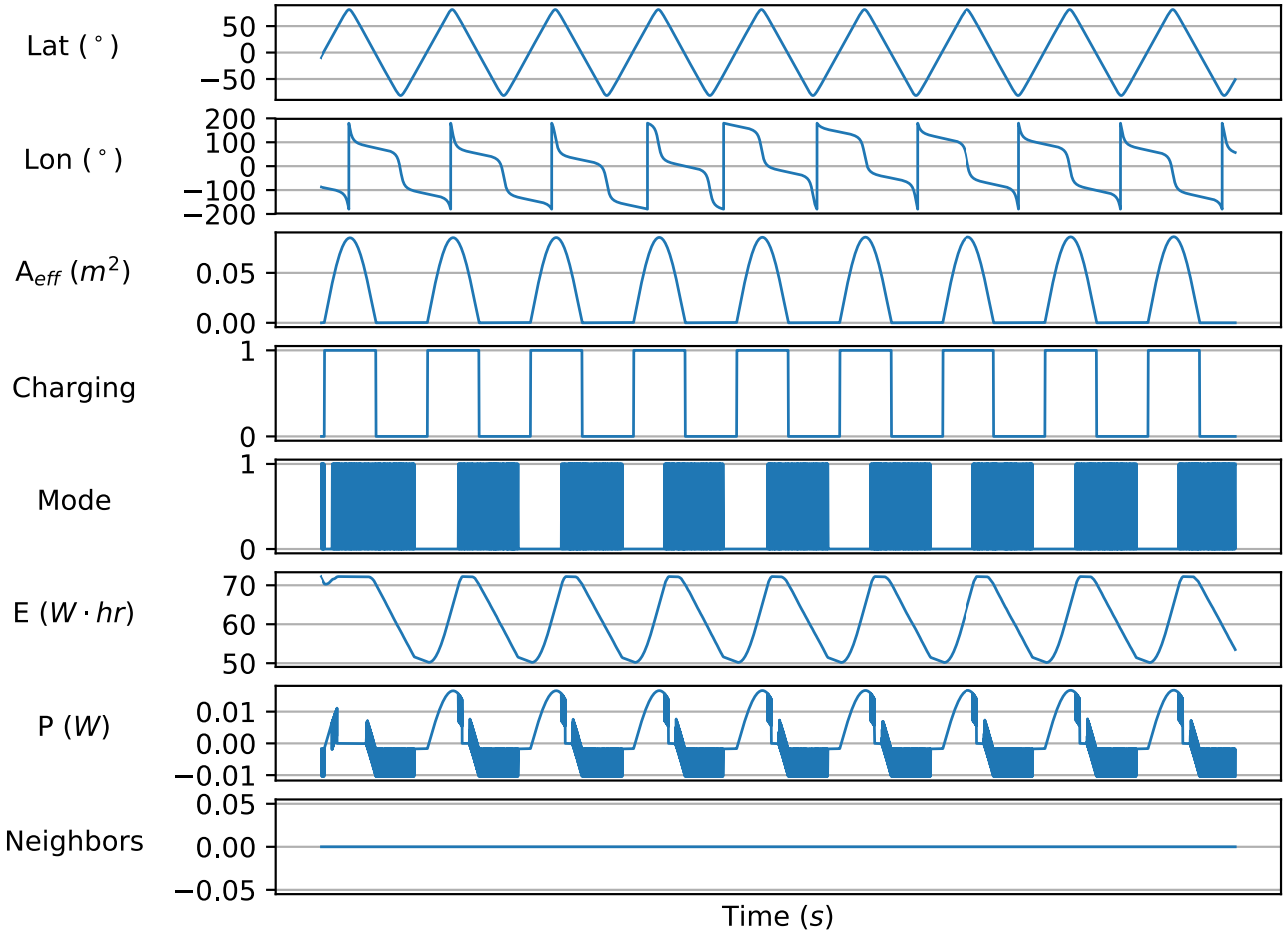
MANAGE: Case Study Baseline Results





MANAGE: Case Study Adaptive Algorithm Results





MANAGE: Preliminary Conclusions

- Baseline algorithm: measurement for fixed percentage of orbit
- No control of power expended vs power charging rate
- Large duty cycles can cause excessive battery discharge
- Proposed algorithm manages power resources :
  1. Adaptive planning of power expense and charging over entire orbit
  2. Guarantees no excessive battery depth of discharge
  3. Maximizes measurements taken at locations of interest
  4. Optimizes measurement taken during charging and eclipse phases

COLLABORATE: Library

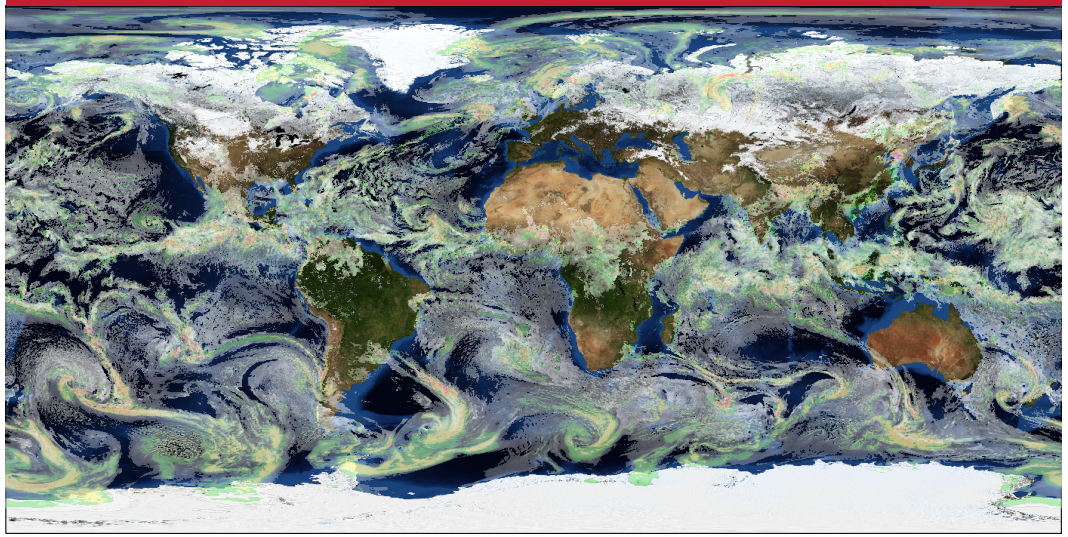
The COLLABORATE library provides a generalized, abstract interface and structure for the simulation of collaborating constellations

- COLLABORATE library therefore:
  - Generalizes the concepts from MANAGE to apply a constellation level
  - Models the orbital propagation at a constellation level
  - Models the communications links between constellation members
  - Provides methods to plan message routing strategies

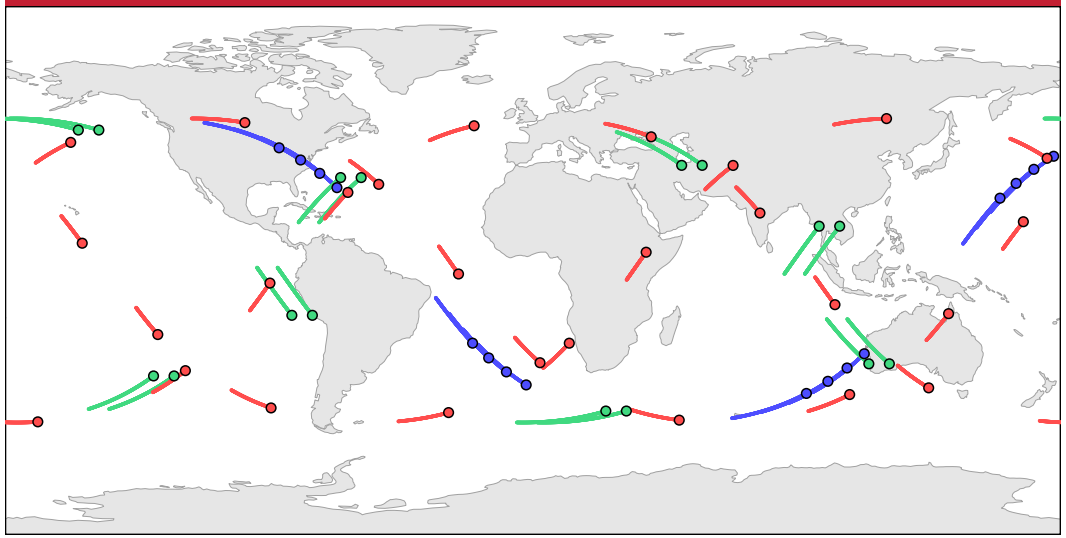
COLLABORATE: Case Study

- **GOAL:** Maximize mission science return through collaboration
- **Truth Data:** NASA GEOS-5 Nature Run
  - 2D 30 minute instantaneous single-level
  - Full resolution single-level meteorology
- **Orbital Data:** Celestrak two-Line element sets
  - Current CubeSat TLEs

Precipitation and Optical Cloud Depth



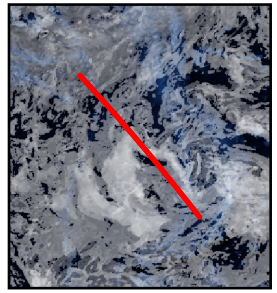
Three Heterogeneous Constellations

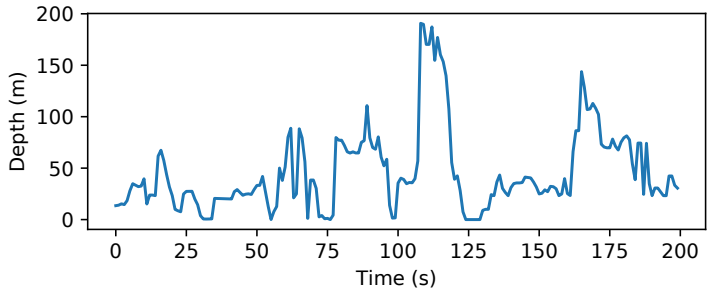


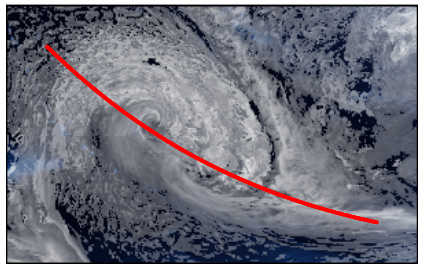
COLLABORATE: Case Study Results

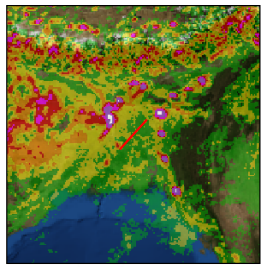
- Satellites sample truth data
- Route prediction algorithm
  - Feed-forward/feed-back
- Cognitive algorithms
  - Regression/classification
- Increased measurement value

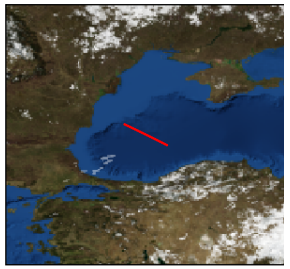
Measurements



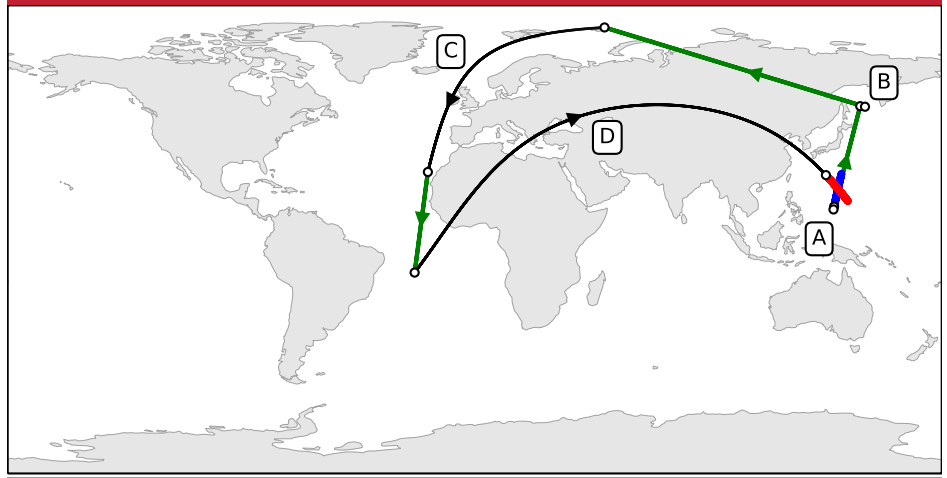


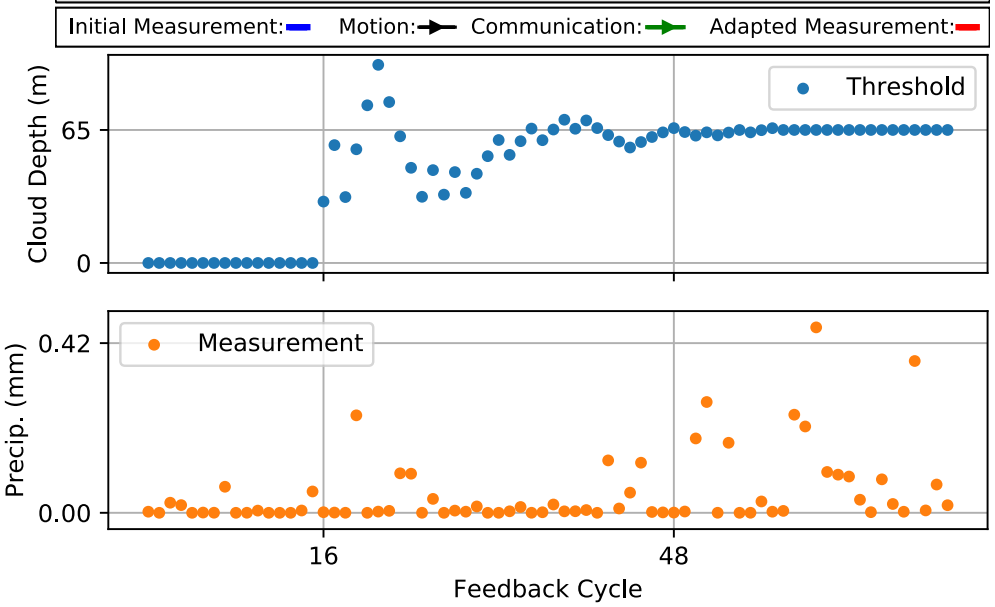






Algorithms





COLLABORATE: Preliminary Conclusions

- Route prediction algorithm enables cognitive networking
  - Perception: Forward route & feedback route
  - Action: Adjust parameters & update internal models

- Exploit meteorological correlation to optimize operations
  - Identified regions with high clouds through random sampling
  - Clouds radars cue rain sensors to observe those locations
  - Performed regression to target cloud depth threshold (65m)
    - Yields majority (>65%) non-zero precipitation measurements

- Did not rely on data ground link

- Did not rely on human input

Summary & Conclusions

✓Simulation Toolset for Adaptive Remote Sensing: August completion

✓Comprised of three libraries:

- ADAPT
- MANAGE
- COLLABORATE

✓Includes example case studies to assist in use

- There will be a manual and report

✓Case studies already helping to show value of adaptive methods

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