Jet Propulsion Laboratory
California Institute of Technology

Planning and Execution for Front Delineation and Track with Multiple Underwater Vehicles

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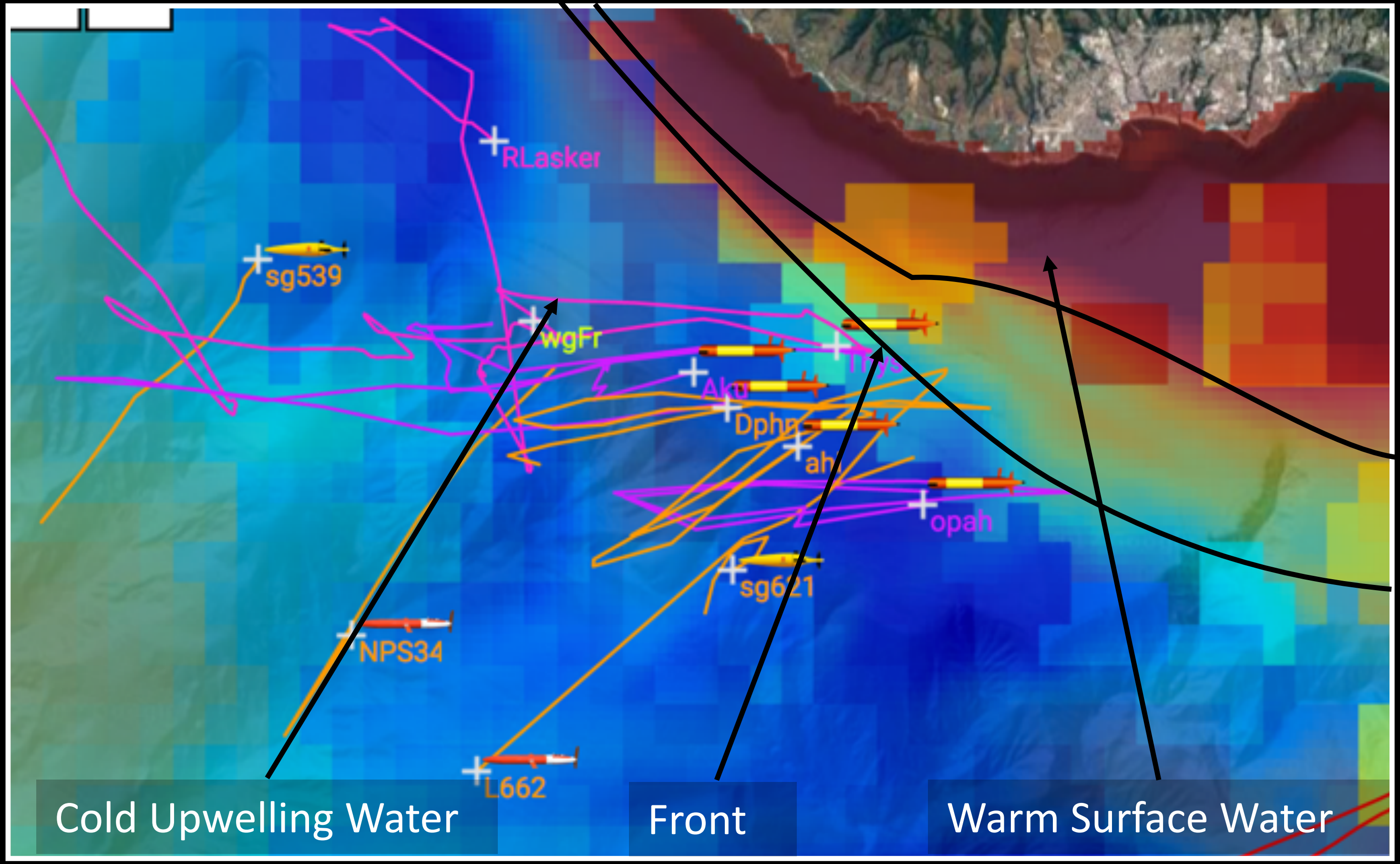
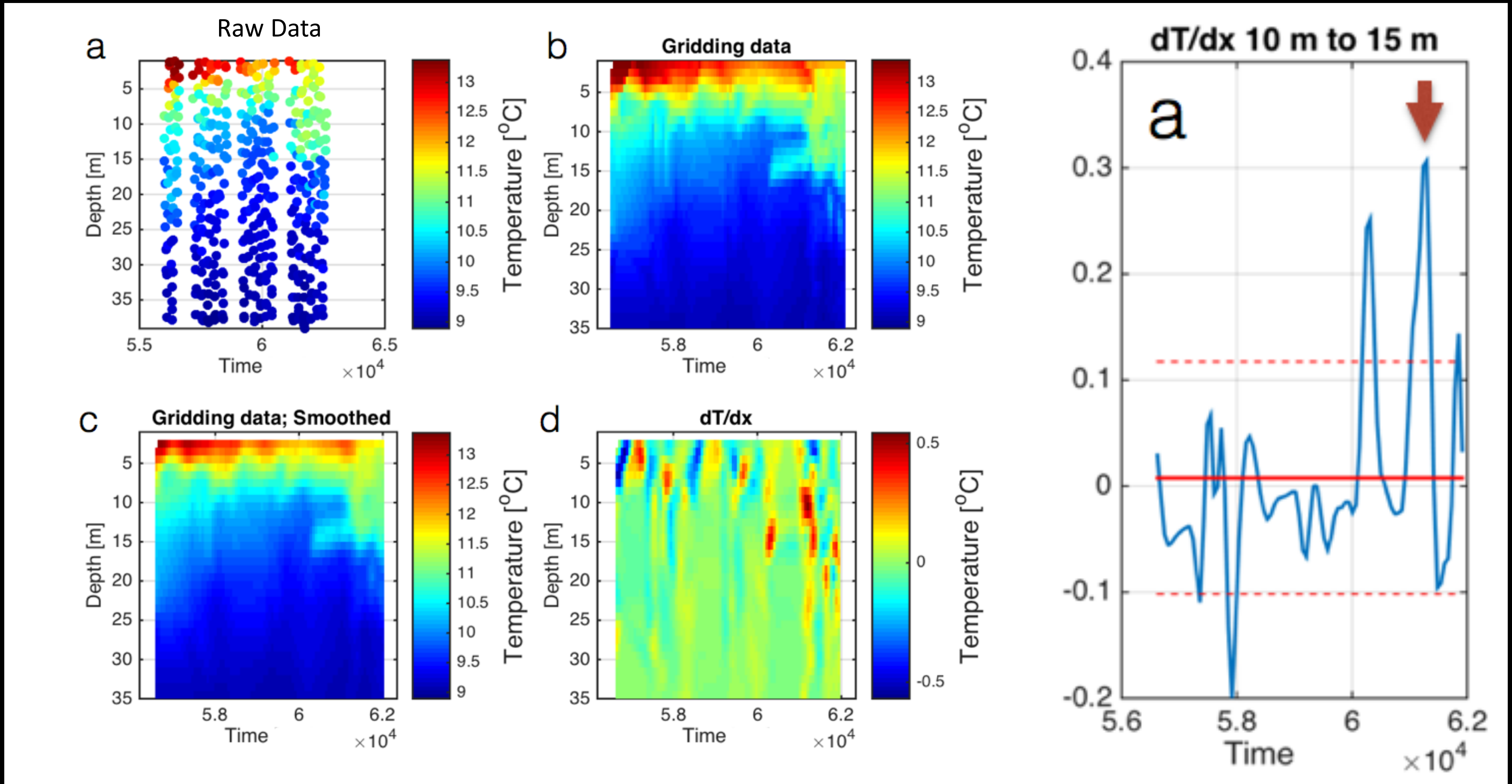
Tracking Ocean Fronts

- Ocean front is the boundary between two distinct bodies of water
- Goal: Repeated transects across an ocean front
- Temperature is shown however any water property can be used



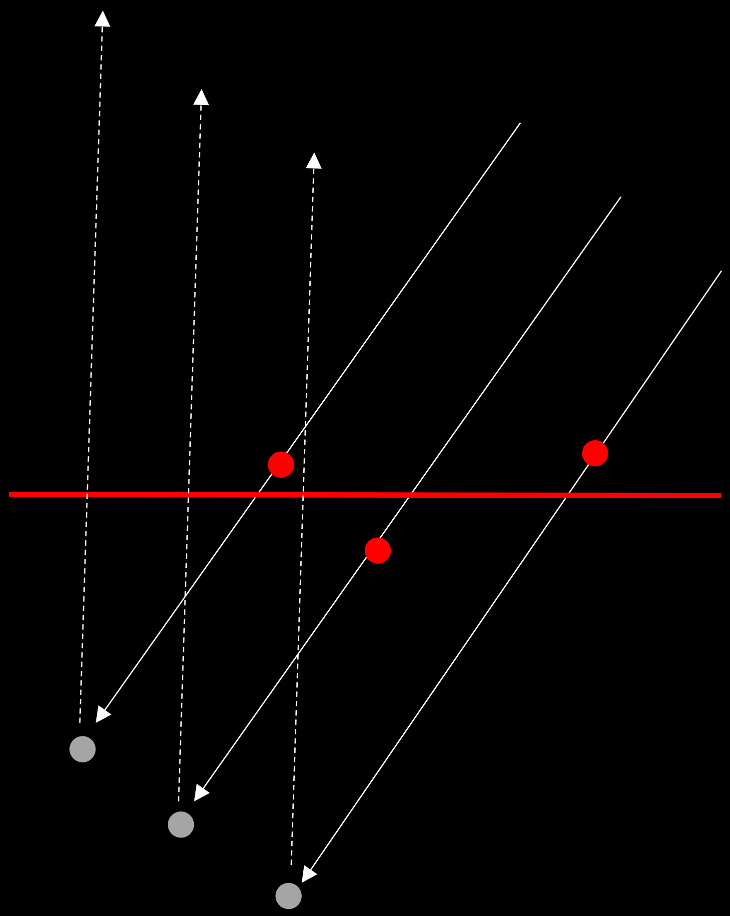
Lateral Gradient Front Detection

- Detect a change in water property over a transect
- Grid, smooth, and differentiate transect data
- Sum data over specified depth
- Declare front when over threshold value
- Select front from declared fronts



Front Delineation and Tracking

- Given multiple vehicles in near parallel transects
- Estimate a linear front from detections
- Command vehicles perpendicular to that front
- Vehicle synchronization is not guaranteed



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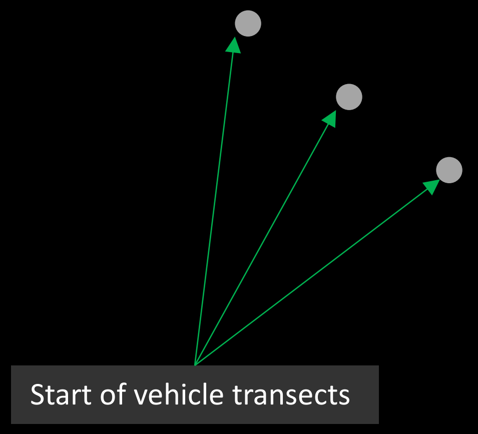

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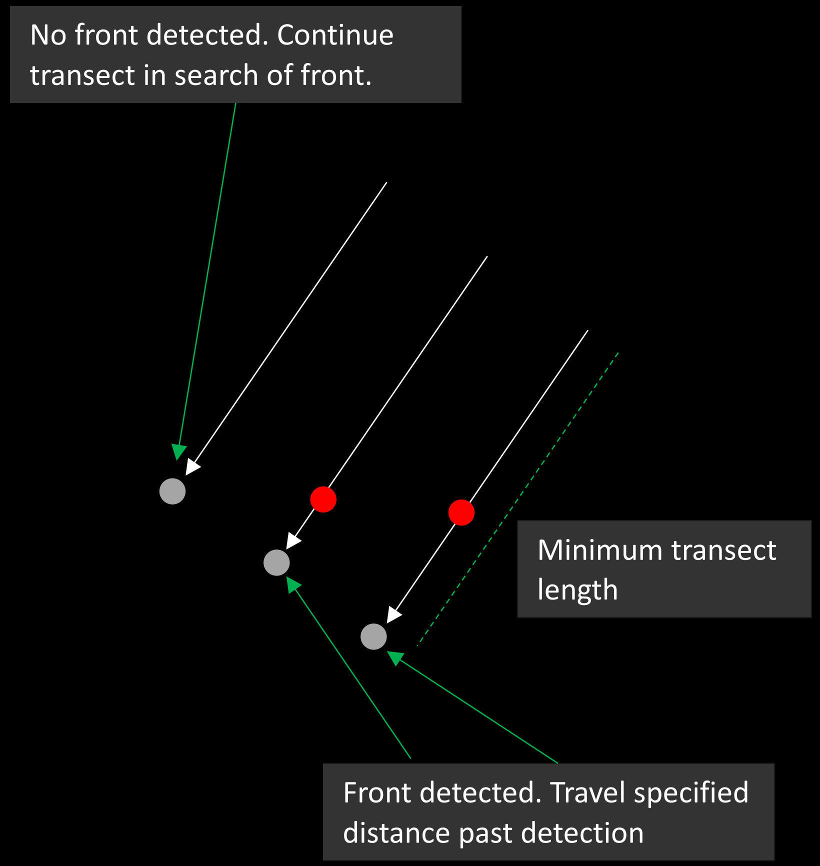

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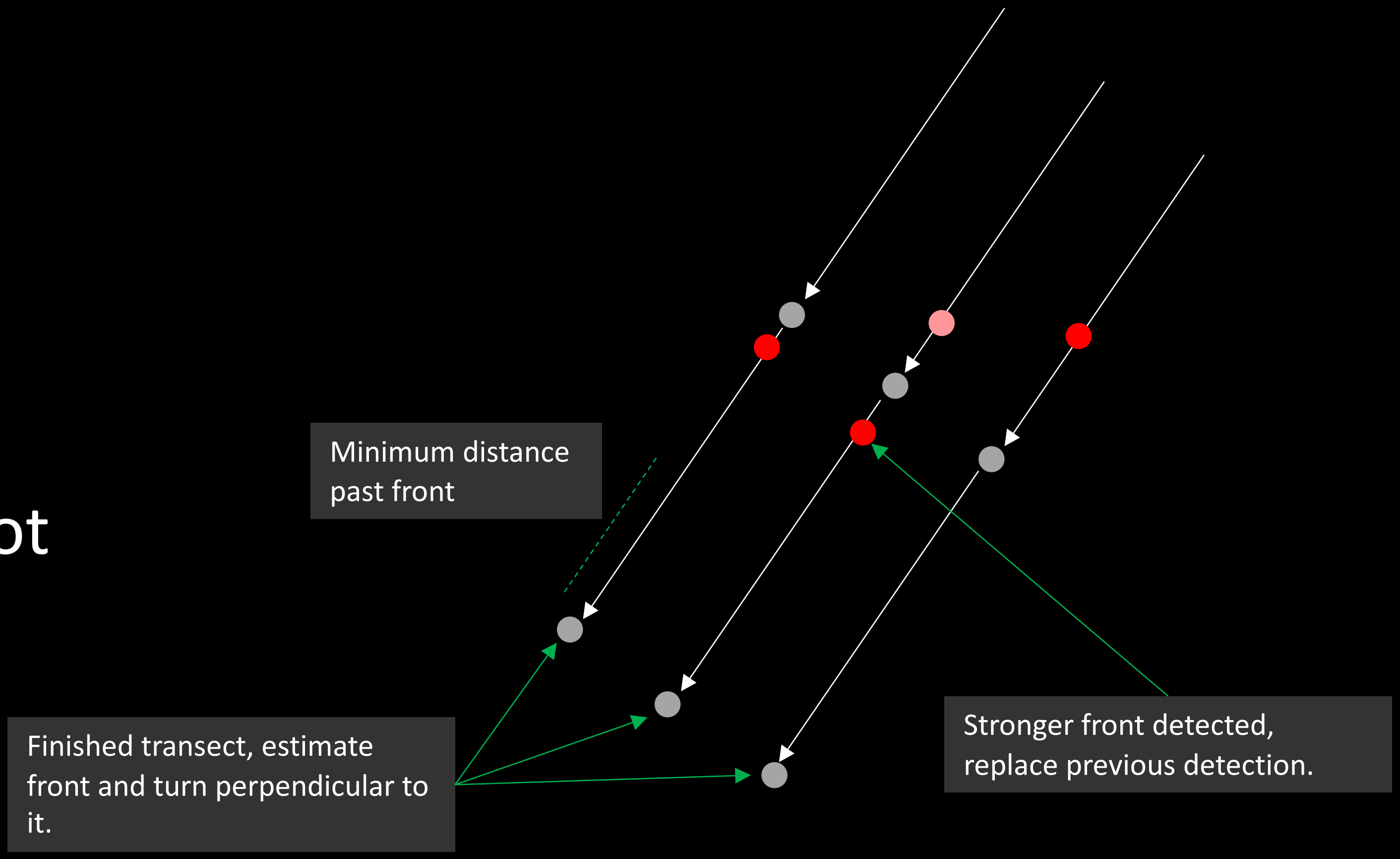

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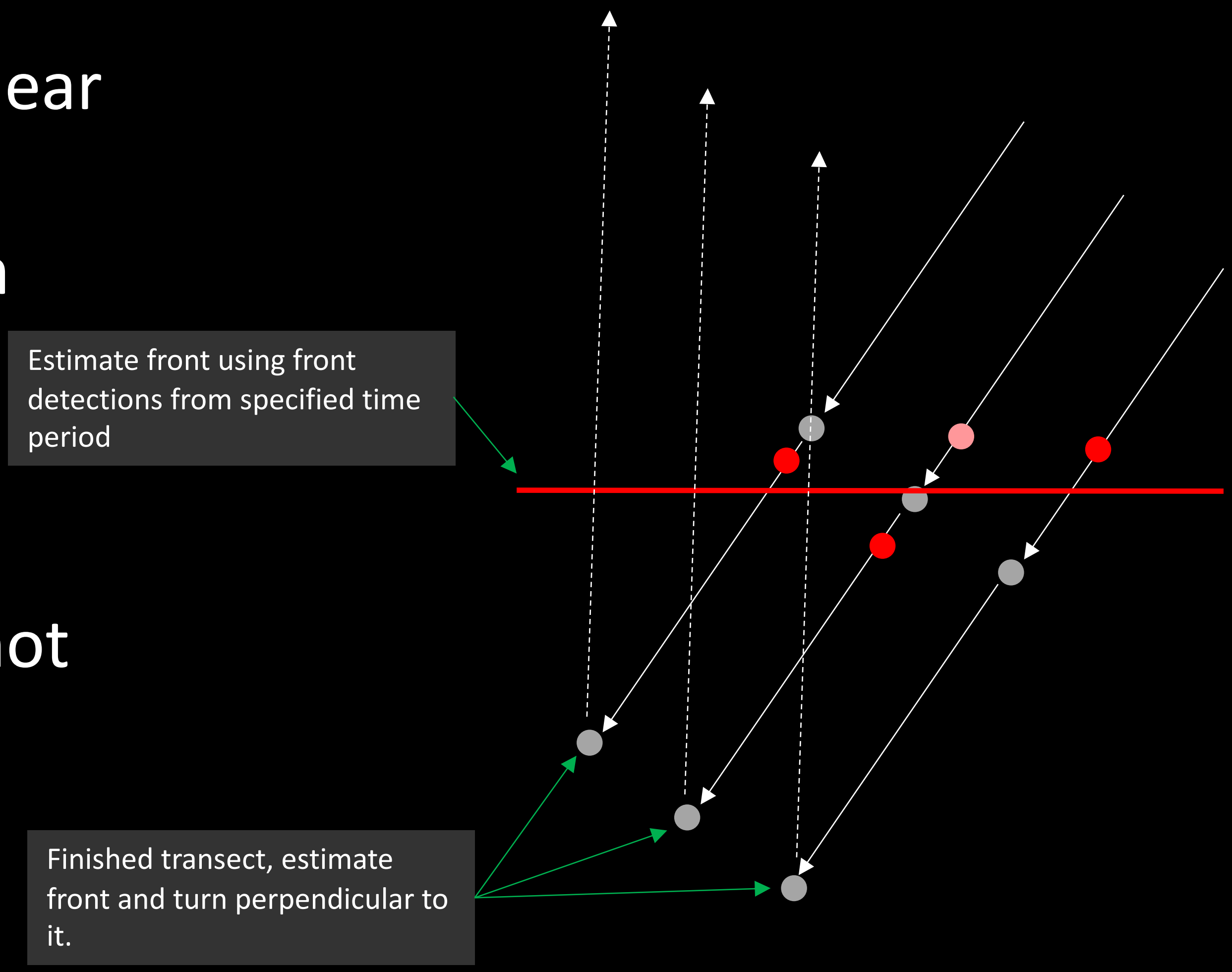
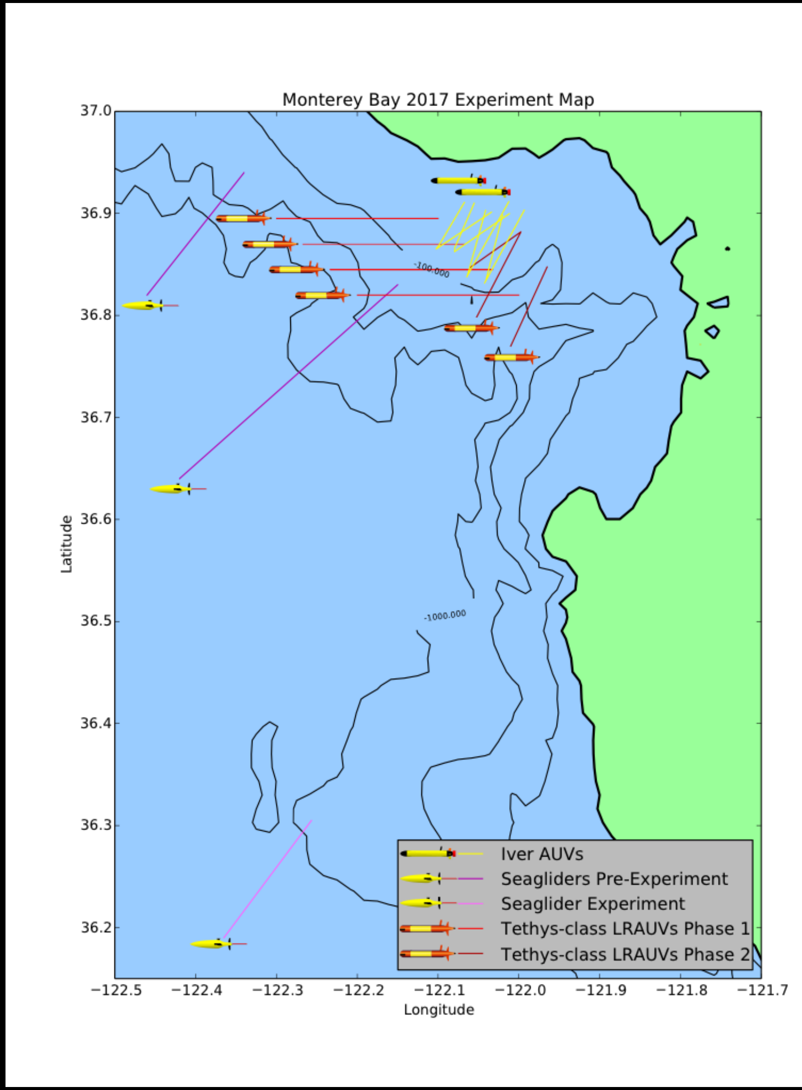


May 2017 Monterey Bay Deployment



Shana Rae

- Front Detection and Estimation
- High level vehicle control

Iver AUV (2)

- 2-4 knots
- ~12 hour endurance

On-shore

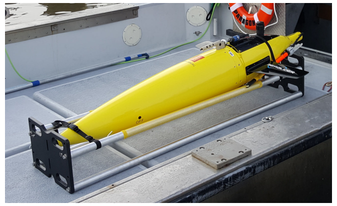
- Front Detection and Estimation
  - High level vehicle control

LRAUV (5)

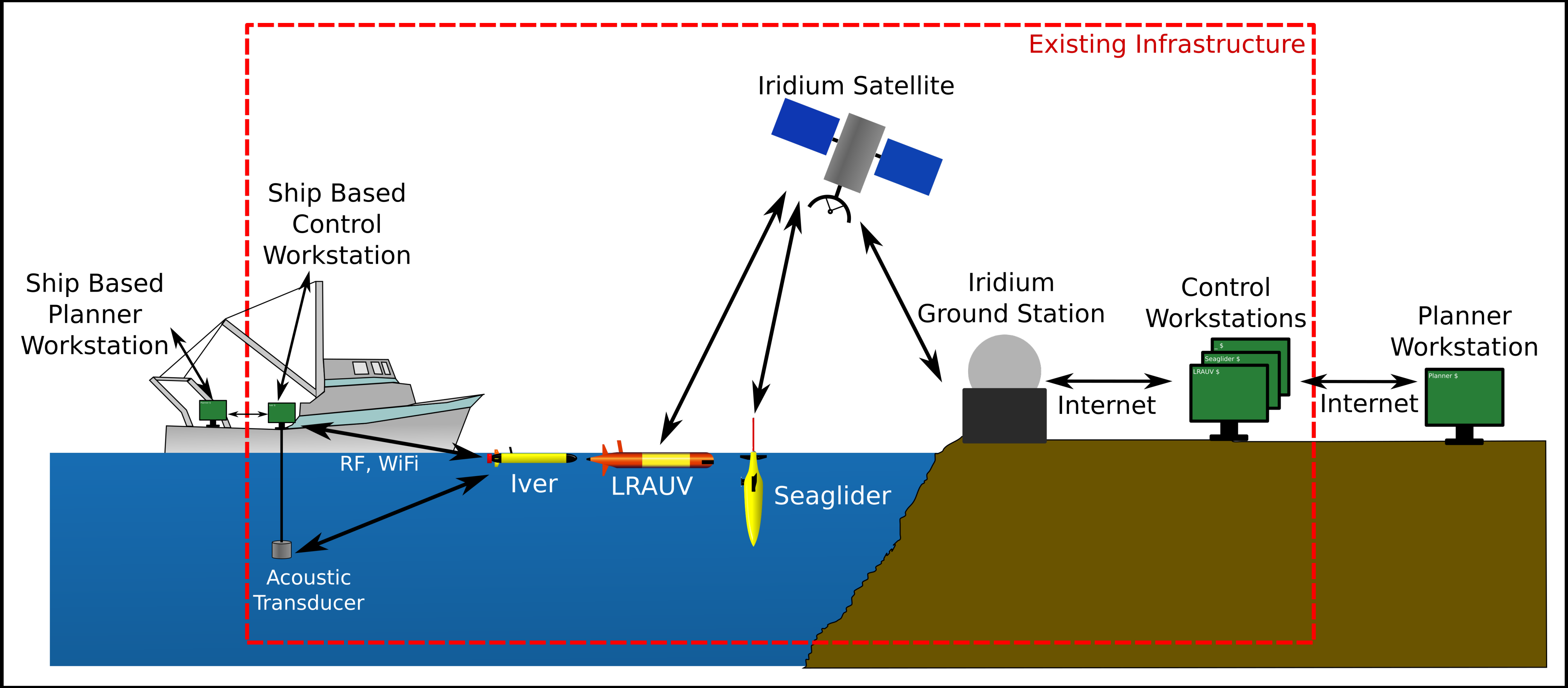
- 1 knot
- Multi-week endurance

Seaglider (1)

- 0.5 knots
- Multi-month endurance

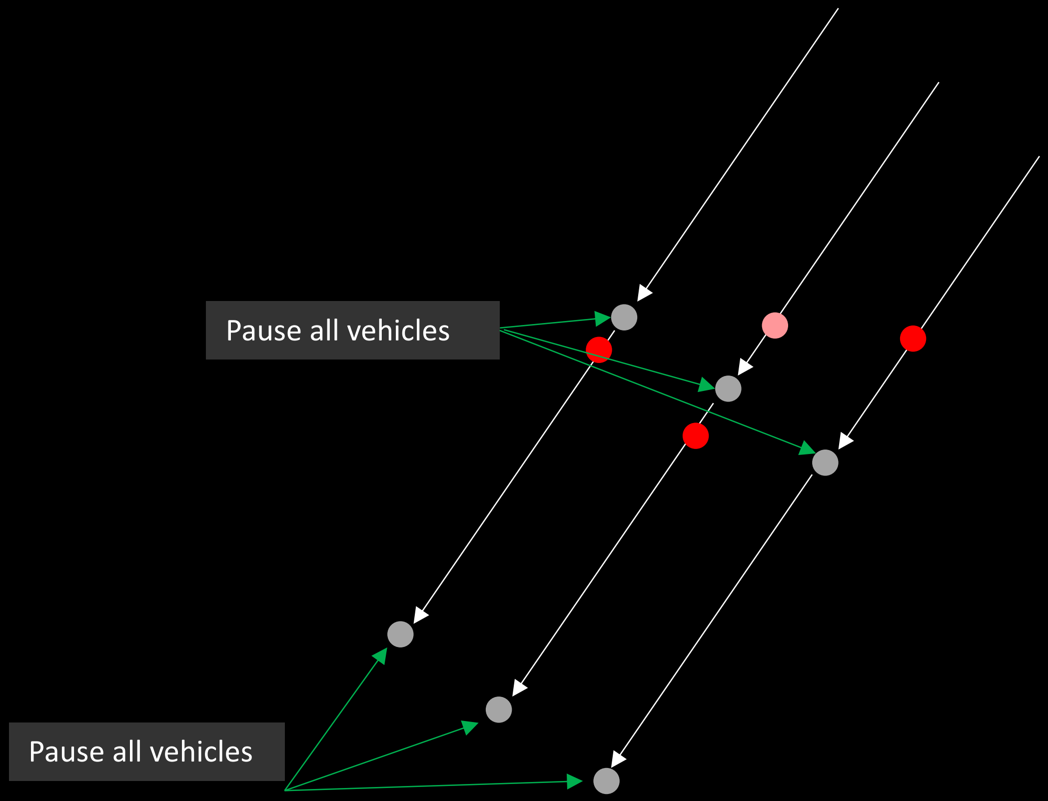


System Architecture



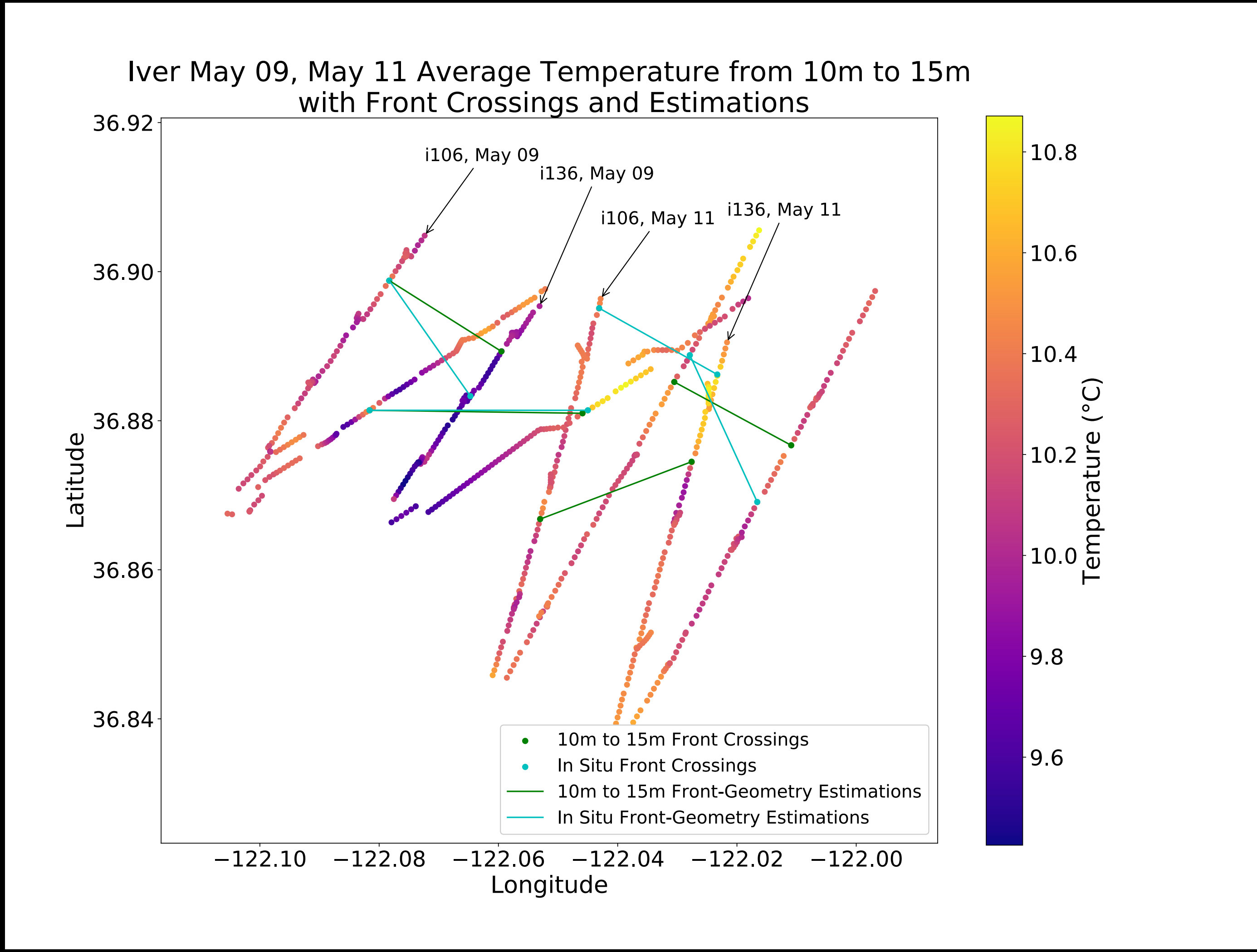
Iver AUV Algorithm Modifications

- Iver AUVs must remain in close proximity for communication and vehicle safety
- Pause at each decision point until all vehicles are present
- Every vehicle either continues transect or turns and starts next transect



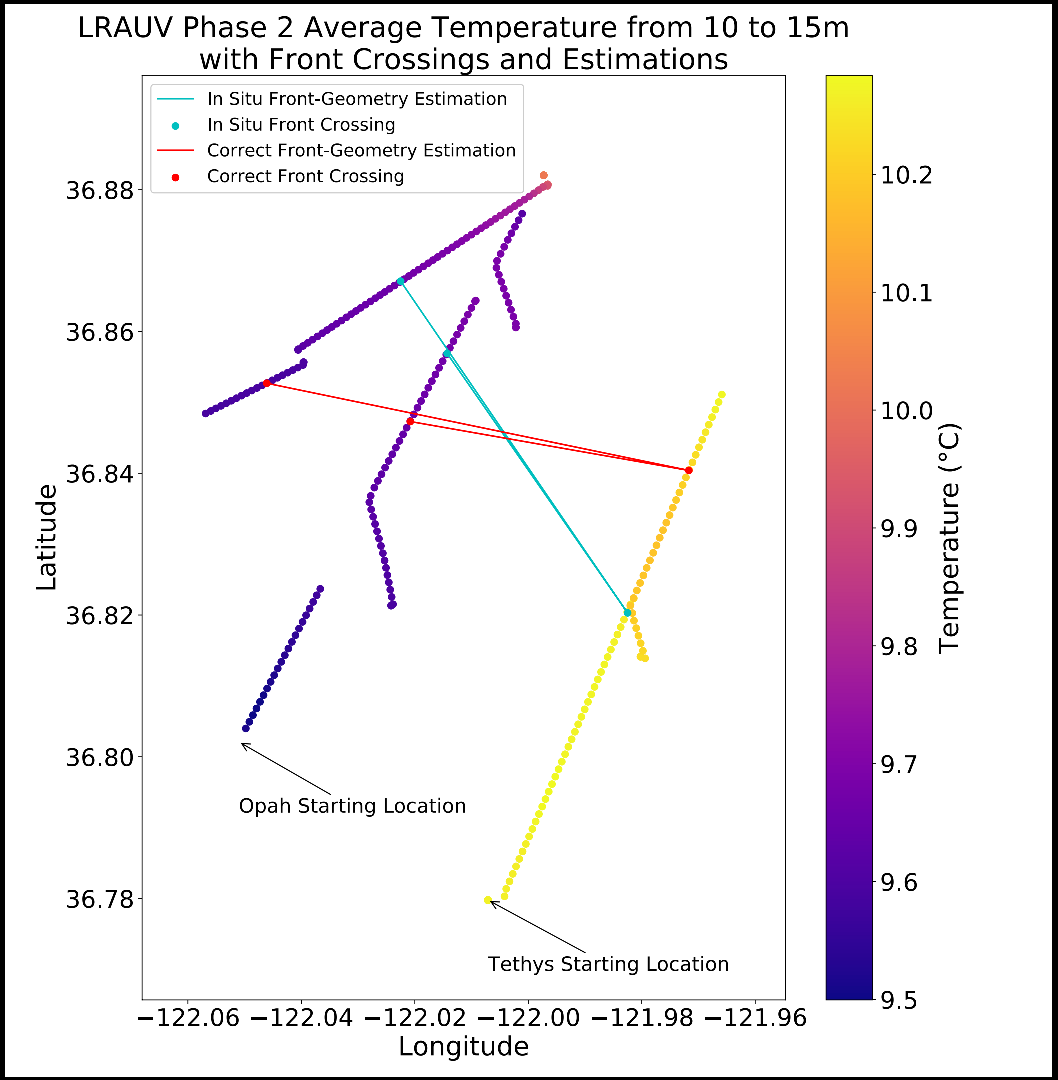
Iver AUV Experiment

- Minimum transect distance set to 2.5 km past previous estimated front
- If no front was detected in initial transect, continue 2 km
- Vehicles set to turn around immediately after a front is detected



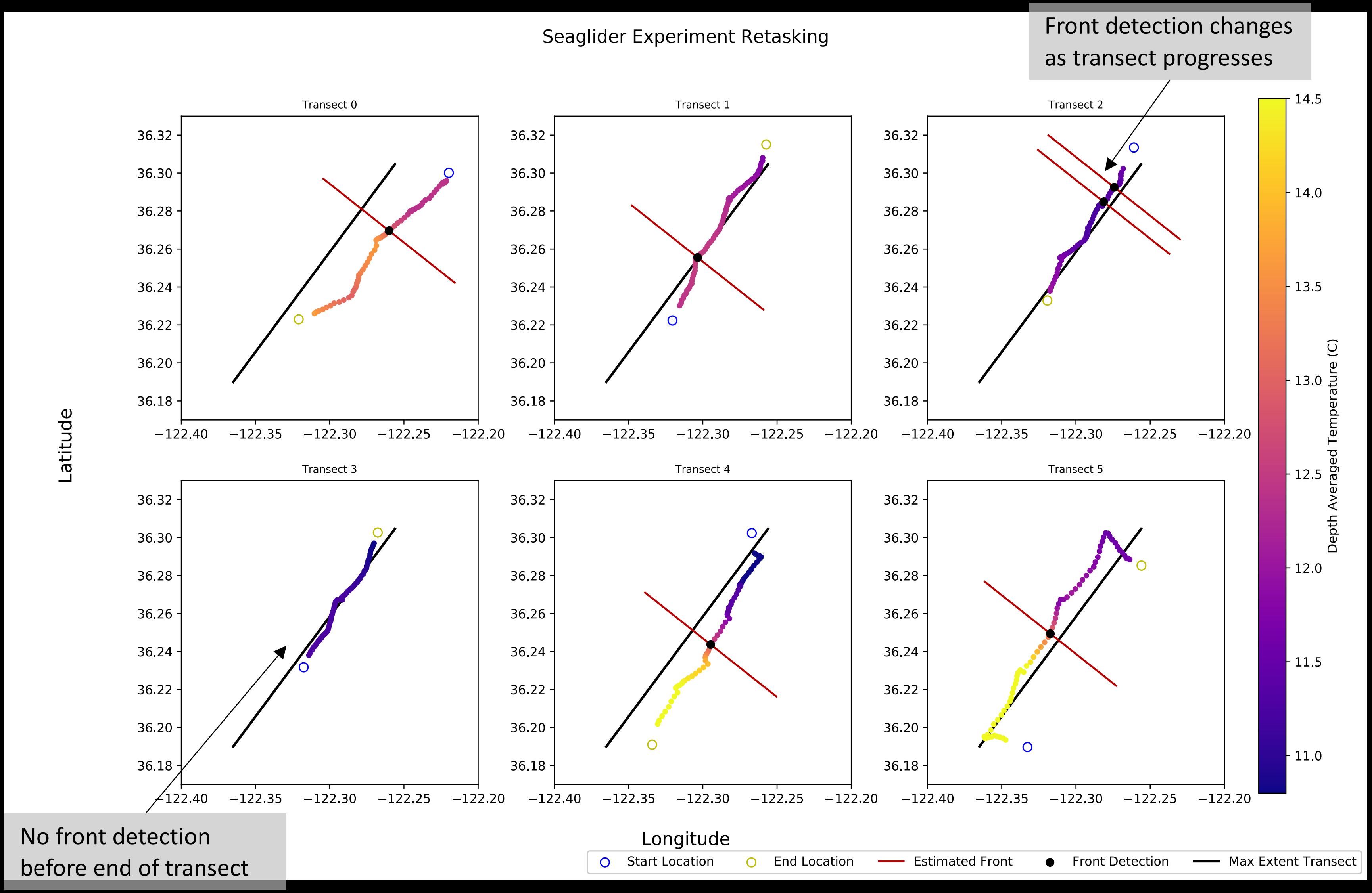
Long-Range AUV Experiment

- Minimum transect distance set to 4.5 km past previous estimated front
- Vehicles set to turn around immediately after a front is detected
- Software error led to incorrect front estimations



Seaglider Experiment

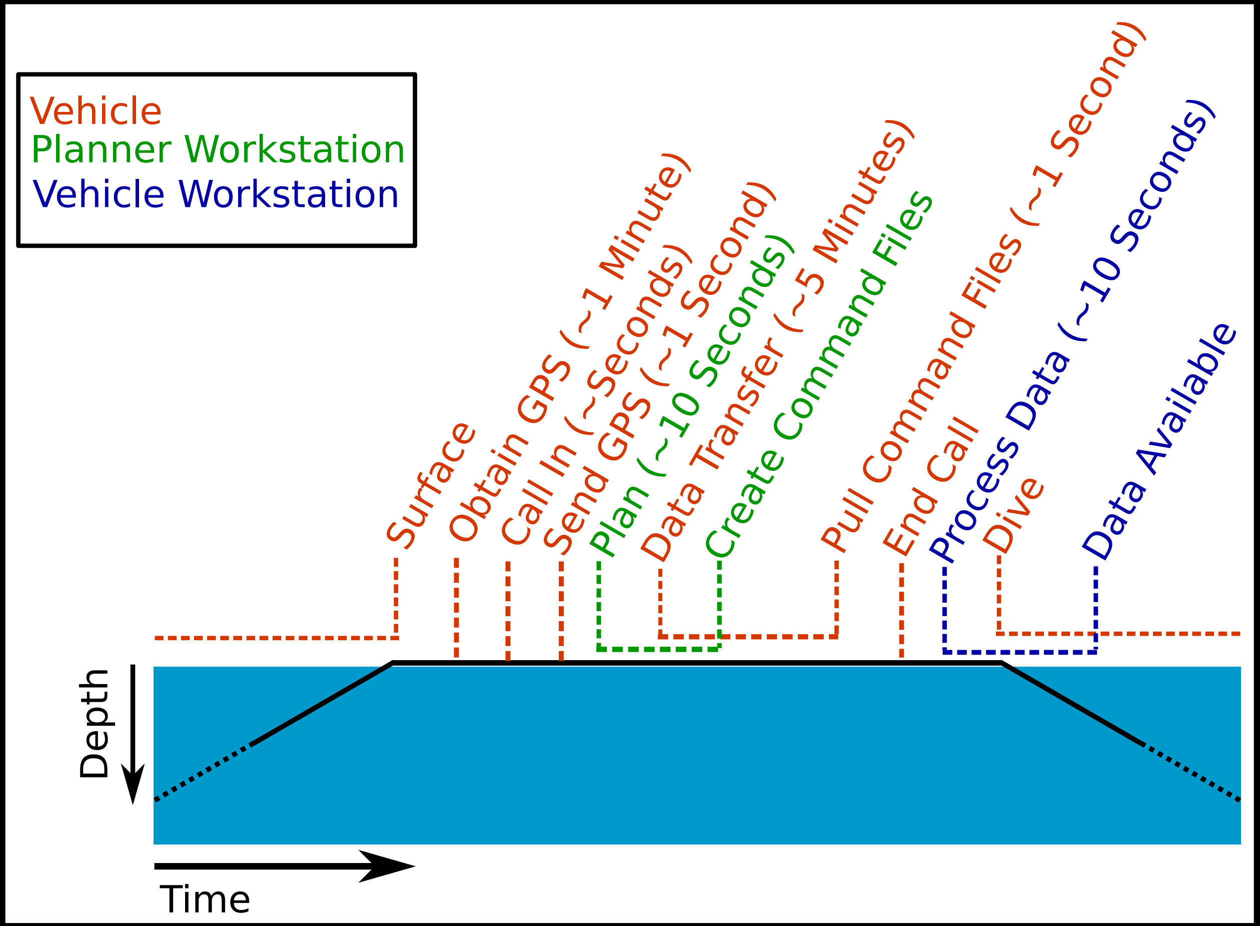
- Single vehicle is available, so a fixed front orientation is assumed
- Minimum transect distance set to 5 km front start of transect
- Distance past front: 5 km
- Short distance parameters due to limited testing timeframe



Planning and Execution Challenges

Communication Paradigms

- Centralized offboard planning system
- Required communication for planning and coordination reduces real-time capabilities
- One dive delay in data availability for Seaglider and LRAUV

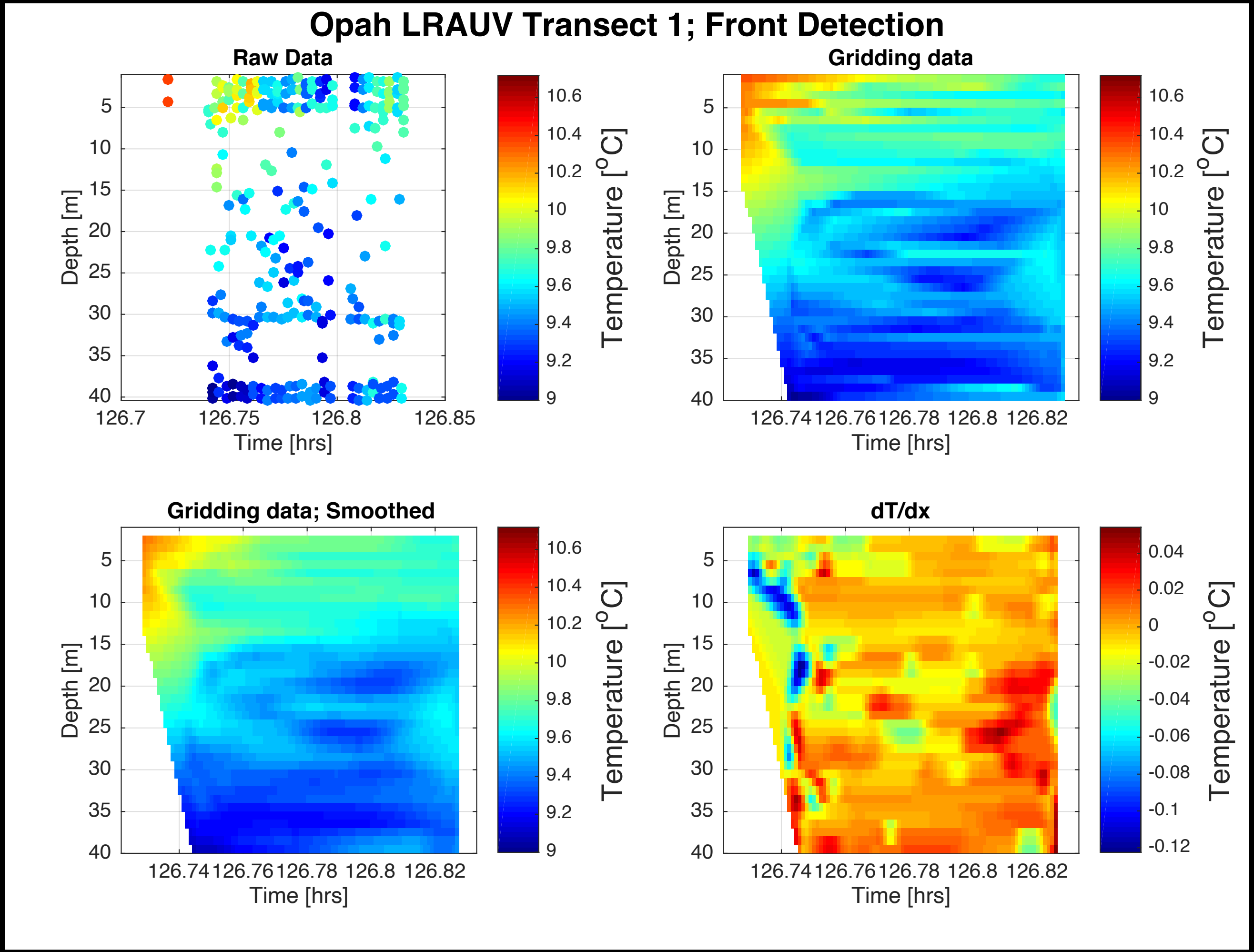


Planning and Execution Challenges

Data Decimation

- Communication over Iridium or acoustic modem can require data decimation

- LRAUV data decimation + interpolation technique resulted in suboptimal data gridding



Onboard Planning

- Onboard planning with offboard coordination
  - Real-time response with single vehicle
  - Real-time use of full dataset
  - Coordination requires communication with shore
  - Unique implementation per-vehicle type
- Onboard planning and coordination
  - Real-time vehicle coordination
  - Allows operations when shore-based communication is unreliable (under-ice)
  - Requires peer-to-peer vehicle communication

Conclusion

- Develop method for autonomous tracking of ocean fronts using multiple vehicles
- Demonstrated a proof of concept in Monterey Bay, CA with Iver AUVs, Tethys-Class LRAUVs, and Seagliders
- Laid groundwork for future onboard implementation of front tracking techniques

Future Work

- More deployments and testing
  - Direct comparison between fixed transects and front tracking
- Adding the capabilities to distinguish between fronts
  - Warm-to-Cold vs. Cold-to-Warm
  - Sharp vs. gradual
- Higher fidelity front model
- Onboard implementation of front tracking

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