# Planning for AUVs: Dealing with a Continuous Partially-Observable Environment

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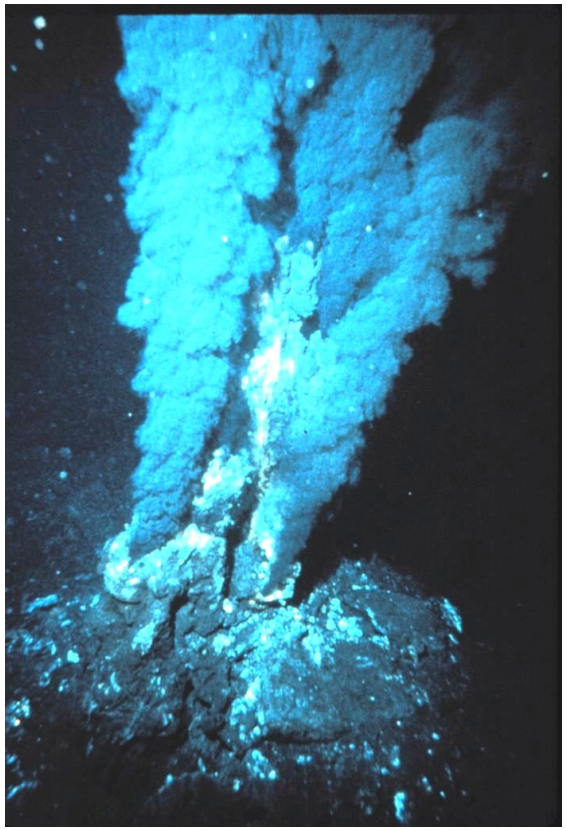
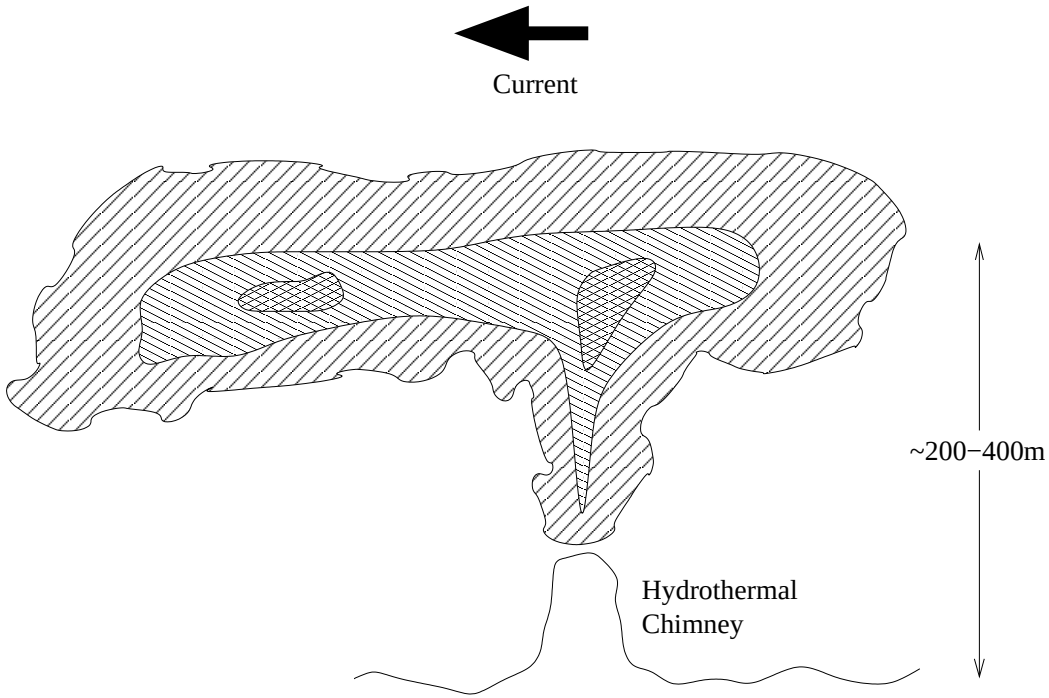
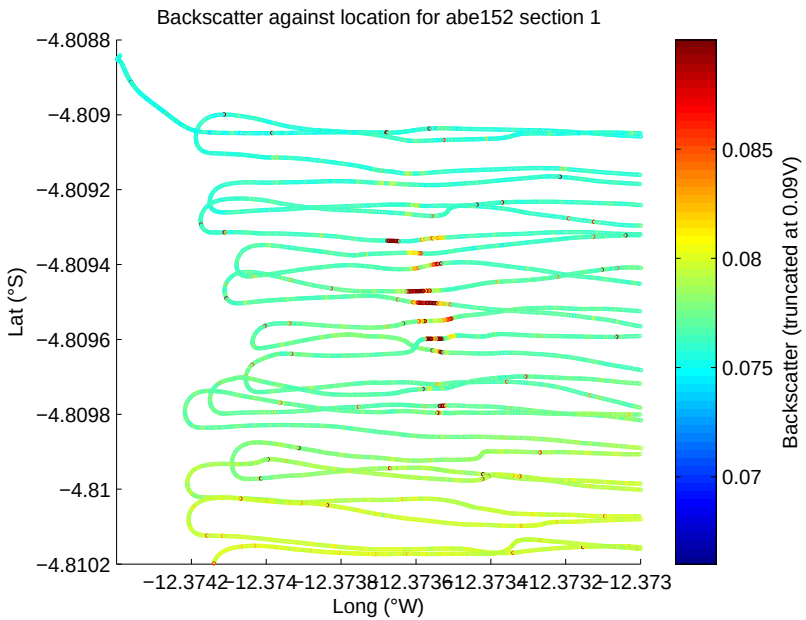
# Oceanography Motivation






- Hydrothermal vents (Black Smokers)
- Found in *vent fields* on ocean floor
- Water heated by magma, dissolves chemicals and metals, and erupts into ocean

# Problem Description

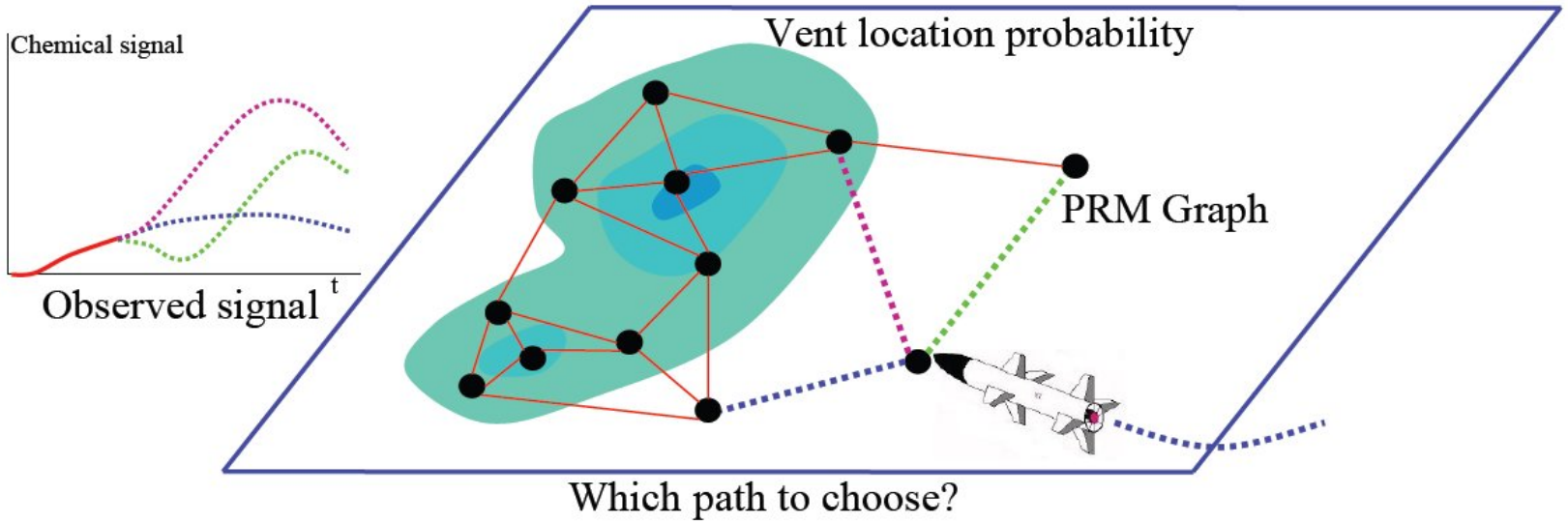

**Aim:** Enable AUV to locate as many hydrothermal vents as possible within constraint of available battery power.

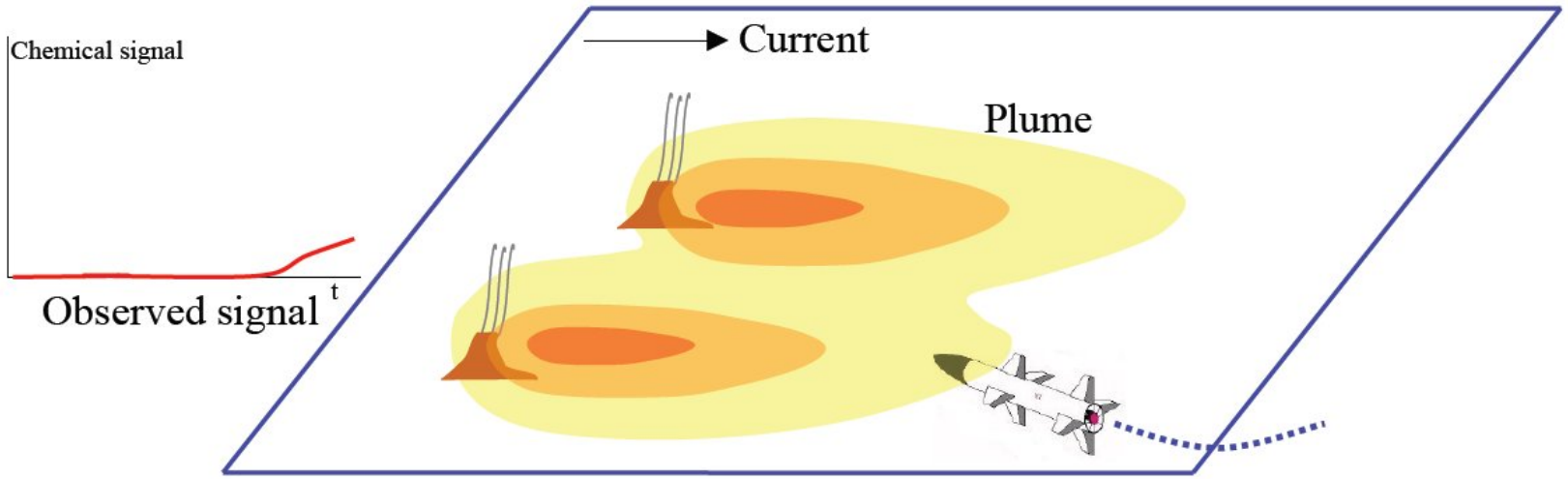
- AUV has
  - Sensors to detect tracers, e.g. manganese, particle density
  - Accurate knowledge of its location

# Planning Challenges

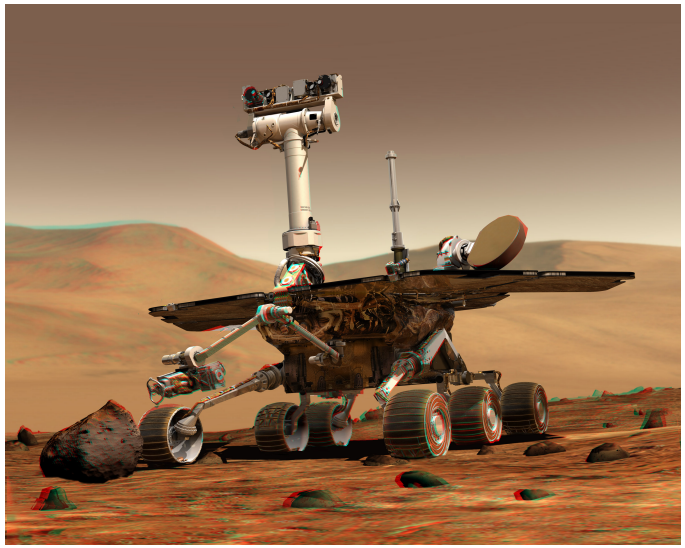
- First, have to estimate the state, given observations so far
  - This means building a probabilistic map of vent locations
  - Hard problem due to multiple sources and vague range information from sensors
- Next, have to plan actions, given the probabilistic map
- This implies planning with:
  - Partially observable and unknown state
  - Continuous state, action and observation spaces
  - Uncertain action outcomes
  - Limited resources for executing the plan
- Very important to consider the informational value of actions

# The Decision Problem



# Related Work



- Mars rover work handles planning with continuous state spaces and limited resources (Bresina et al. 2002; Dearden et al. 2003; Mausam et al. 2005)
- Ideas from model-based reinforcement learning are also relevant
- Partially-observable Markov decision processes (POMDPs) can deal with uncertain state and uncertain action outcomes (Smallwood and Sondik 1973; Kaelbling et al. 1998)
- Tractability is barrier to using POMDPs

# Summary

- The vent-prospecting problem poses an interesting planning challenge, due to partially-observable continuous state space, and limited resources
- Our ideas:
  - Use particle-filter approach for mapping
  - Use a Probabilistic Roadmap planner, combined with expected entropy reduction in the map at each node
  - Expanded on (a bit) in the paper
- We're open to suggestions!