Background

- B.S. Mechanical Engineering, Cornell University
- 1st Year PhD Student (Aerospace Engineering Systems - Controls)
  - Advisor: Dr. Eric Frew
- Hobbies: Skiing, Hiking, Biking, and Camping
Recent Research Projects
Cloud Seeding with sUAS
Cloud Seeding with sUAS

- Active seeding programs in 52 Countries worldwide (WMO)
- < 55 Domestic Seeding Programs (CO, ID, WY, UT, NV, ND, CA, AZ, NM, TX)

- In Colorado:
  - Snow is the primary source of water supply (~80%)
  - Silver Iodide
  - < 20 Seeding machines in Eagle, Grand, Pitkin, and Summit Counties
  - Supported by utility companies and ski areas (Breck, Keystone, WP)
Cloud Seeding with sUAS
Cloud Seeding with sUAS - Mission overview
Cloud Seeding - Future Work

- Integration and testing of onboard instruments
  - Spring - Fall 2019

- Autonomy Algorithms
  - Summer 2019

- Storm chasing mission with STORM/TORUS
  - May-June 2019
Autonomous Drifter Deployment
Autonomous Drifter Deployment

S. Swenson et. al
Autonomous Drifter Deployment

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Autonomous Drifter Deployment

- Psuedo-Lagrangian Drifter (moves as if a particle in the wind)
- Fixed volume drifter (~constant altitude)
- ~2km altitude is zero-buoyancy altitude
- Stochastic, time invariant wind field (Gaussian)
- Known estimate of wind field (from HRRR and WRF-LES)
Autonomous Drifter Deployment
Modeling of Balloon Trajectories
Decision-making framework:

\[ \tilde{a}^* = [a_0^*, a_1^*, \ldots, a_n^*, \ldots] = \arg \max U = \arg \max \sum_{k=0}^{\infty} \gamma^k r(x_k, a_k) \]
Reward Function

\[ r(s_t, a_t) = \begin{cases} 
0, & \text{Balloon not released} \\
\frac{\gamma_1}{\text{abs}(\mu_T - \mu)} + \gamma_2 \sigma^2, & \text{Balloon is released}
\end{cases} \]

\[ c(s_t, a_t) = \begin{cases} 
\gamma_3, & \text{turn left} \\
\gamma_4, & \text{turn right} \\
\gamma_5, & \text{go straight}
\end{cases} \]

\[ U(s_t, a_t) = r(s_t, a_t) + c(s_t, a_t) \]
Algorithm 4.6 Forward search

1: function SelectAction(s, d)
2:     if d = 0
3:         return (NIL, 0)
4:     (a*, v*) ← (NIL, −∞)
5:     for a ∈ A(s)
6:         v ← R(s, a)
7:         for s' ∈ S(s, a)
8:             (a', v') ← SelectAction(s', d − 1)
9:             v ← v + γ T(s' | s, a)v'
10:        if v > v*
11:            (a*, v*) ← (a, v)
12:     return (a*, v*)
Forward Search Algorithm

Horizon = 5

mean_reward = 100
var_cost = 0
Forward Search Algorithm
Future Work
Future Work

- Continuous aircraft dynamics/trajectory planner
- Multiple Balloons and Goal Points
- Smarter MDP Solvers (Branch and Bound, Sparse Sampling)
- Incorporate NOAA Wind Field data

- POMDP - learn transition probabilities and field weights
- Learn wind fields from balloon trajectories
Summer/Fall Plans

- May - June 2019: STORM/TORUS Campaign
  - Data Analysis and Processing
- Summer 2019: UAE Cloud Seeding Project
  - Sensor Integration, Data Structuring and Processing
  - Autonomy Framework
- Fall 2019: Testing and Verification of UAE Aircraft
  - Summer 2020 - Travel to UAE for ~1 month campaign
Questions?