Observing Network Design Applied To Antarctic Surface Observations

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Overview

1. What is observing network design?
2. Application of network design to Antarctica
3. Preliminary results
4. Future work

Purpose of Network Design

If I want to place an observing station, where should I put it?

Want a method that is:

- Objective
- Optimal
- Flexible to adapt to constraints

Method of Optimal Network Design

How do you choose a optimal station?

- Need to pick a metric
- First station: find the point that correlates the most with the metric
- Next station: not as intuitive – must use variance reduction
- Must remove variance explained by the first station, and then find station that reduces the most *residual* variance

The variance reduction is calculated by:

$$\partial\sigma = \left[\frac{\partial J}{\partial x_o}\right]^T (A - A')\left[\frac{\partial J}{\partial x_o}\right]$$

A – A' is the difference between background error covariances. A is updated using an ensemble square root Kalman filter,

$$A' = (I - KH)A$$

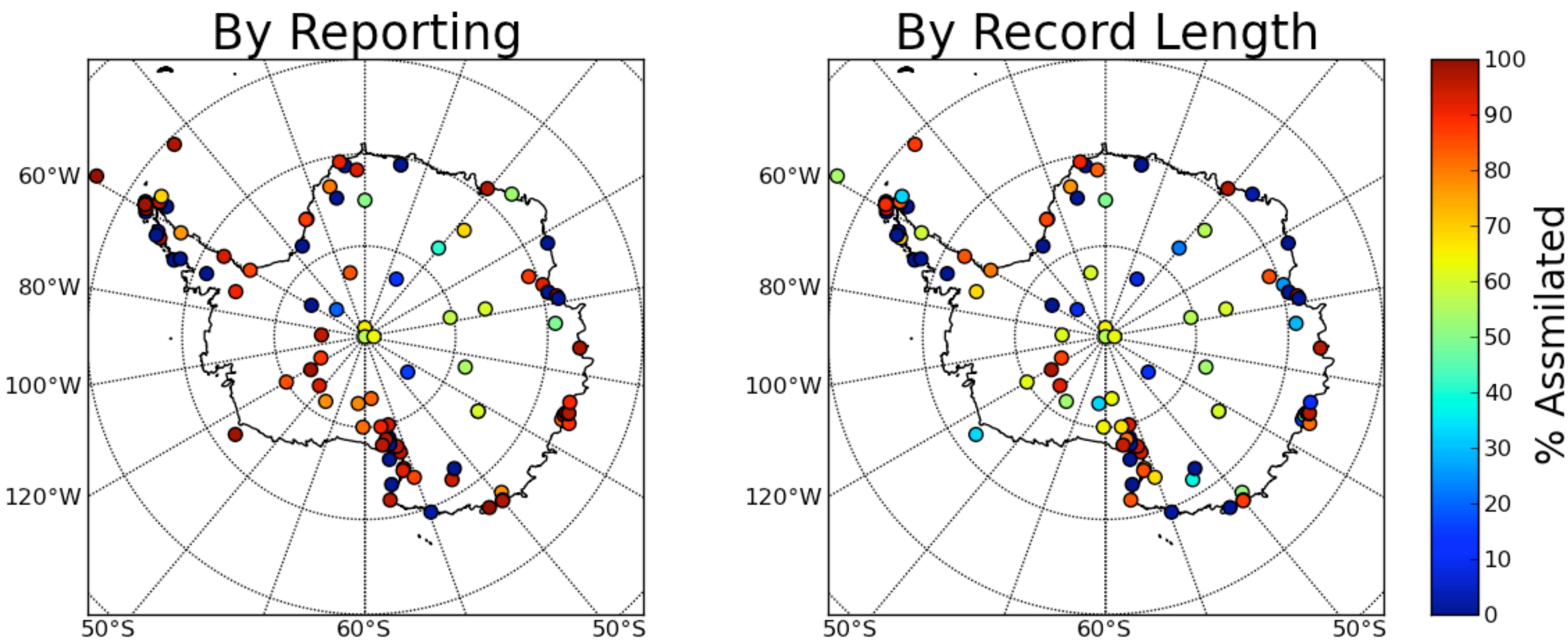
Where K is the Kalman gain and H the observation operator.

The optimal station is the point that maximizes the variance reduction.

Application to Antarctica

- Current network is sparse
- Network design provides an objective method for placing new stations
- Very easy to apply constraints – can mask regions where you don't want to place stations
- Can also use this method to augment the current network

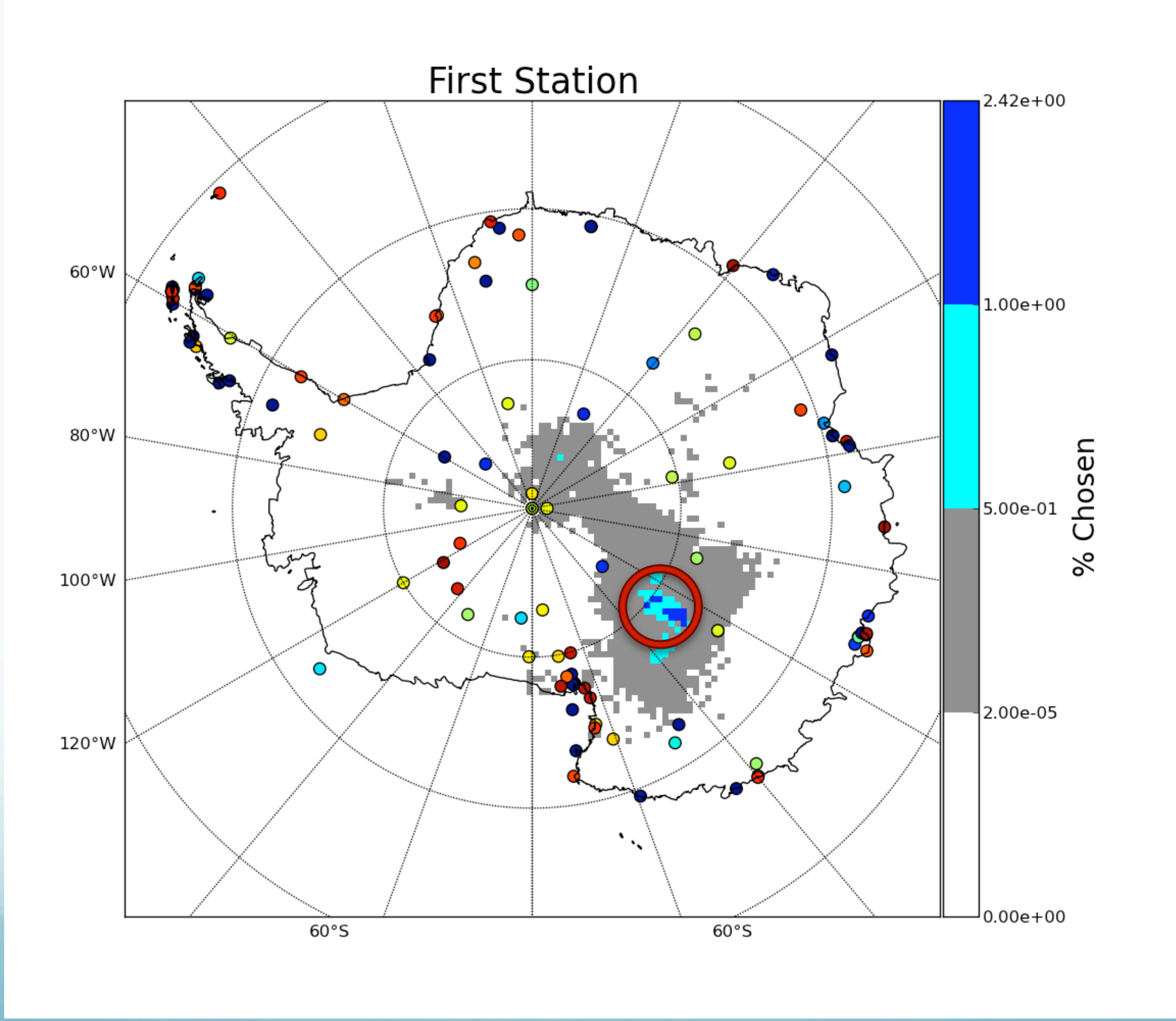
AMPS assimilation statistics



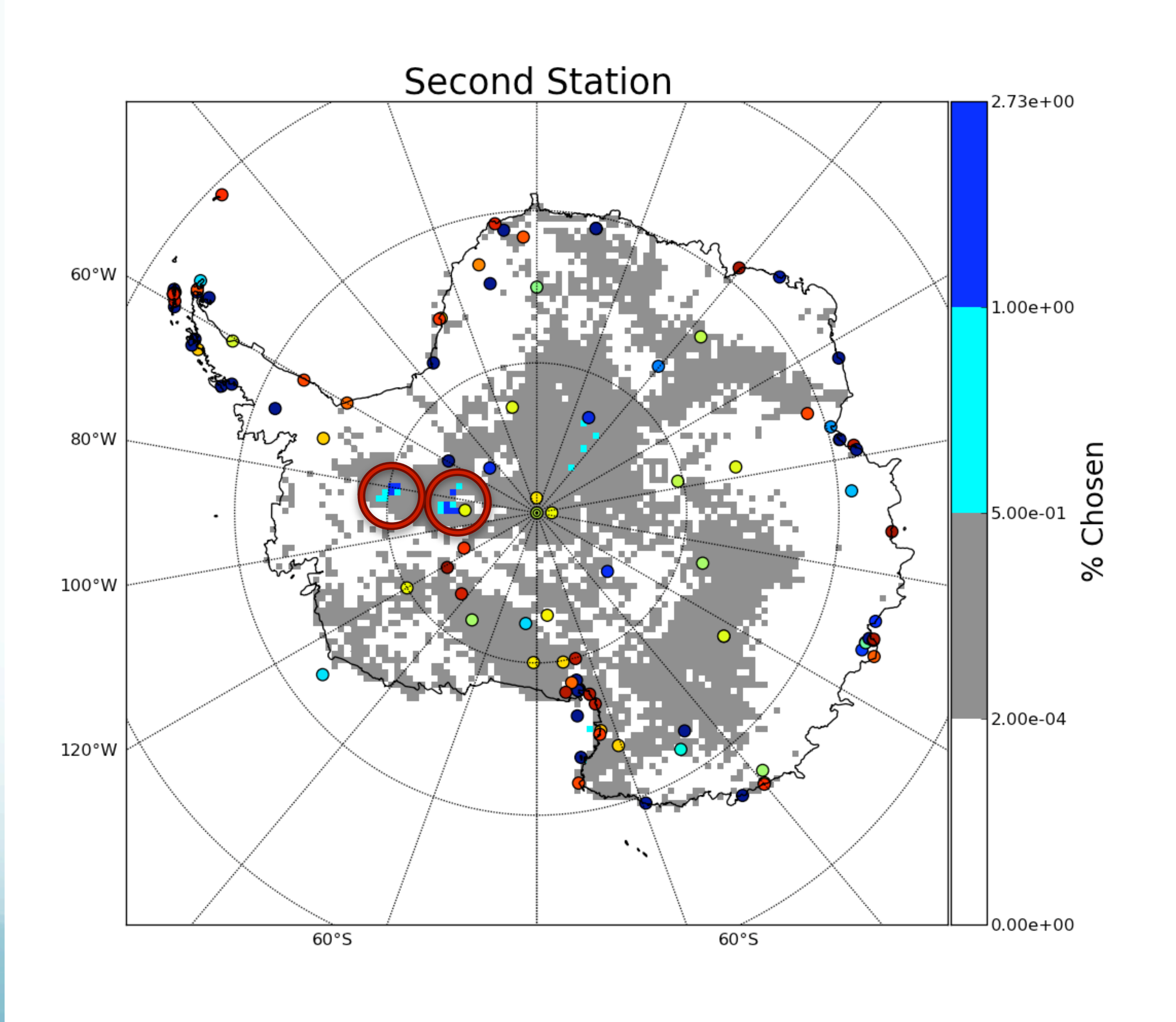
Methodology

- Use Antarctic Mesoscale Prediction System (AMPS) 00Z 2 meter temperature analyses on 15km grid
- Find stations using a Monte Carlo method - a random ensemble from the AMPS data is drawn to calculate the metric and background error covariance, repeated over many trials to account for sampling error
- Determine what locations are optimal to sample continent-averaged 2 meter temperature
- Determine what locations are optimal for the West Antarctic Coast (with the coast masked versus not masked)

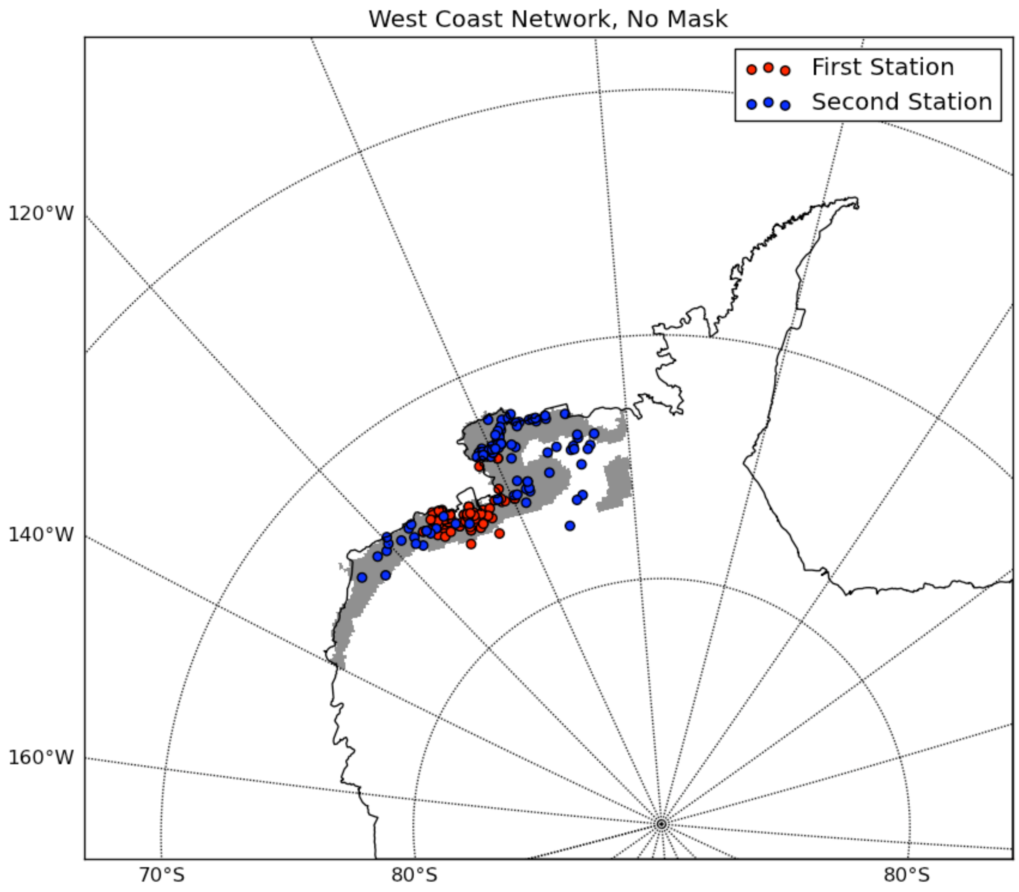
Full Continent Network (50000 iterations)



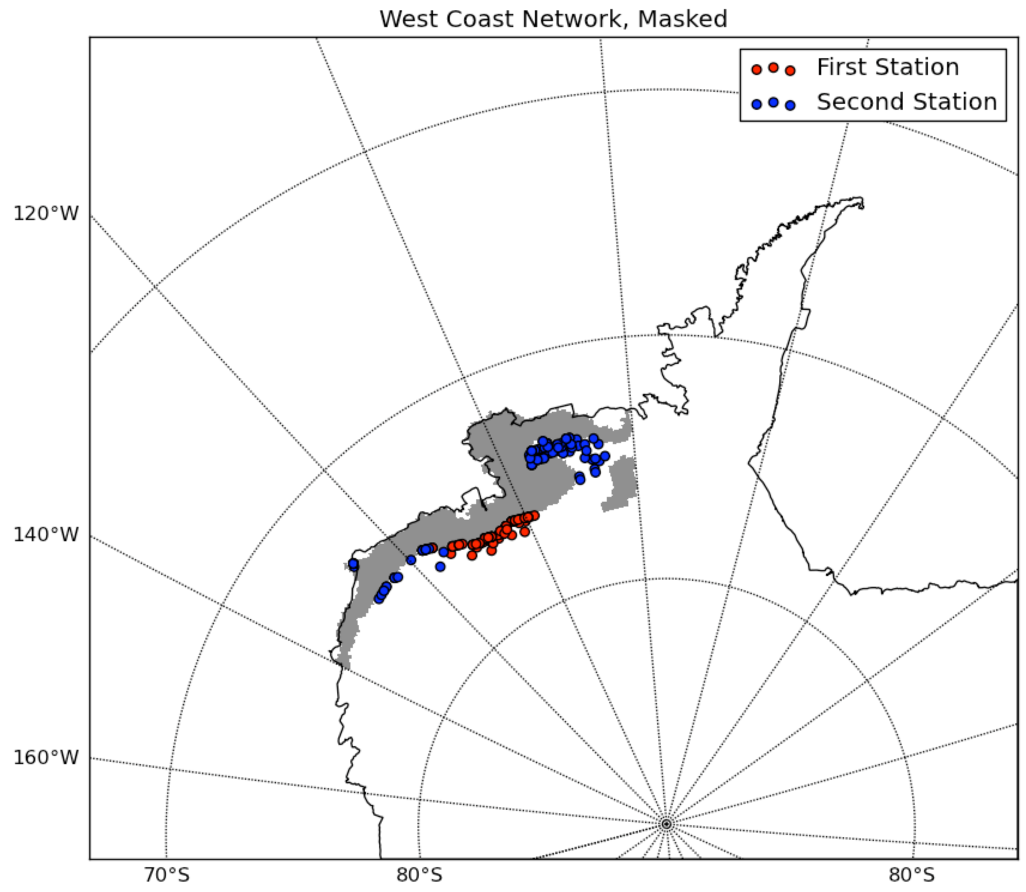
Full Continent Network (50000 iterations)



West Antarctic Coast Monitoring (100 iterations)

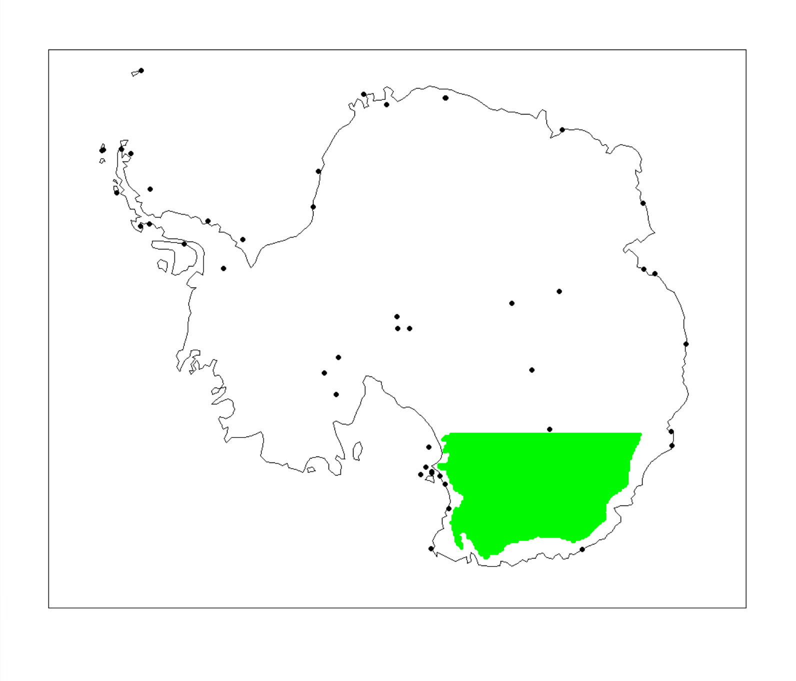


West Antarctic Coast Monitoring (100 iterations)

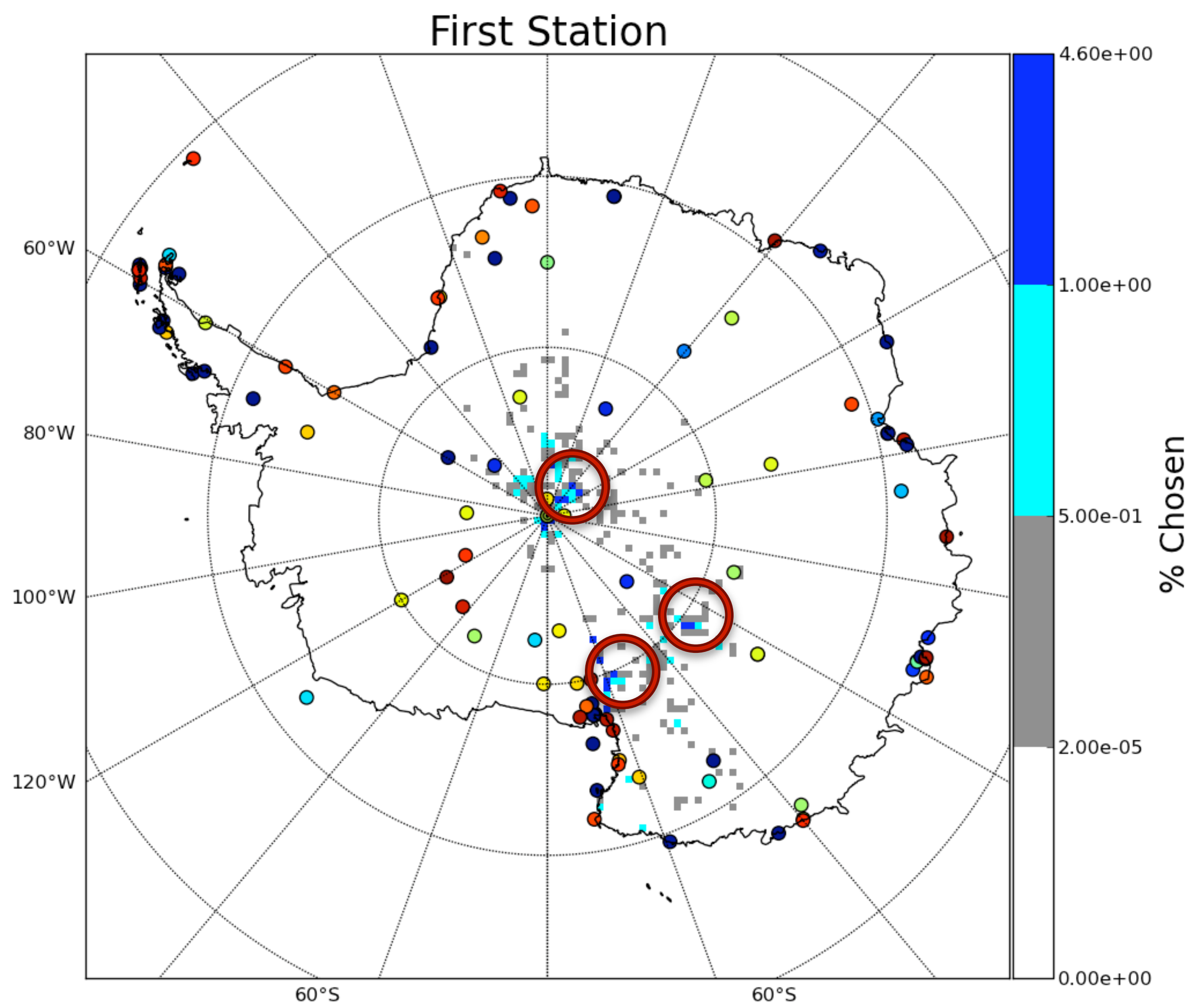


Forecast Error Network

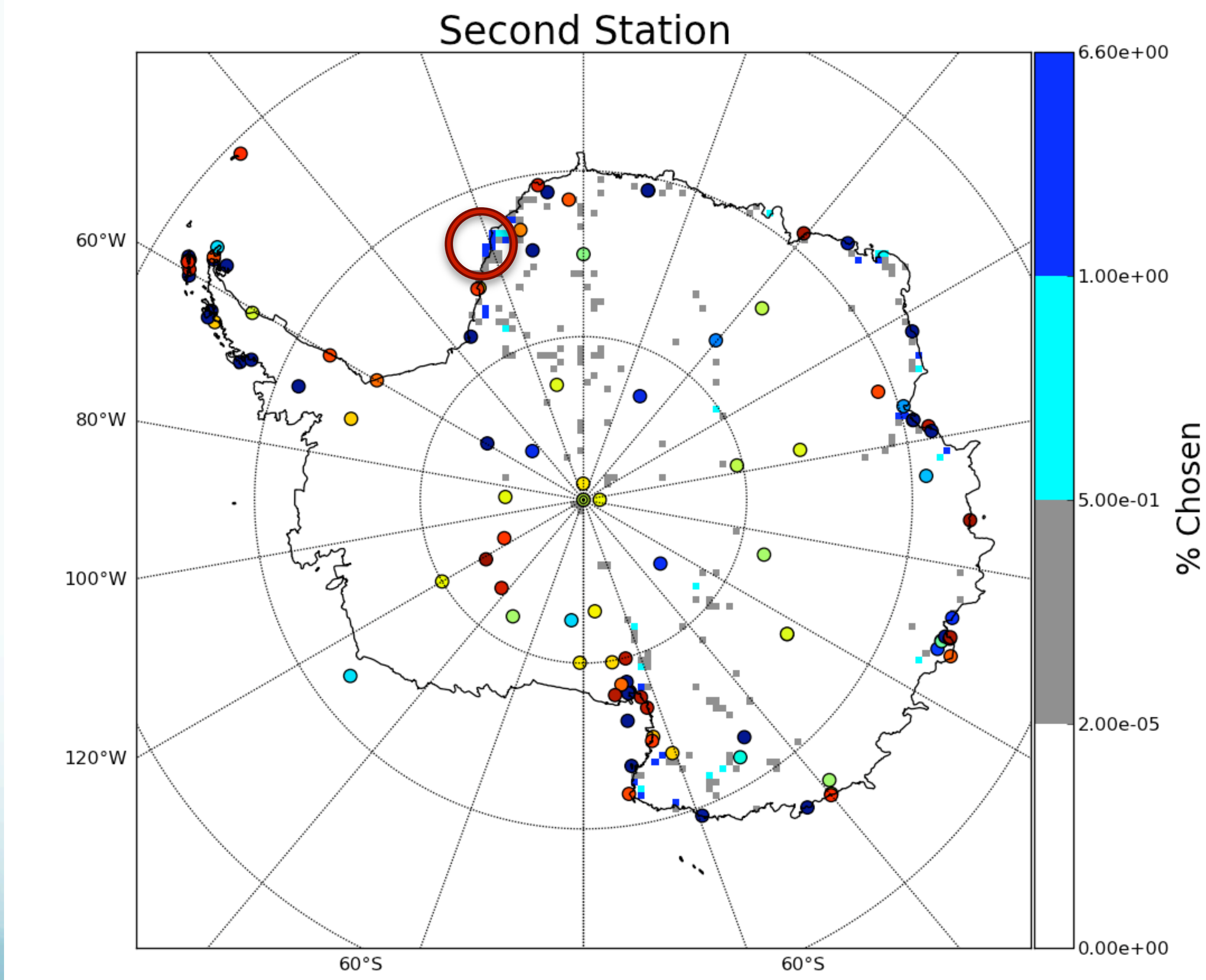
- Where should I measure to reduce 2 meter temperature forecast errors?
- Where to sample to reduce forecast errors in a portion of East Antarctica during austral summer (JF)
- Using AMPS data, but now area-averaged forecast error is the metric



Forecast error network (500 iterations)



Forecast error network (500 iterations)



Future Work

- Run more trials for ideal networks, compare to the current network
- Perform data denial experiments with the current network
- Optimizing in a multivariate sense – how do you optimize for more than one metric?
- Need input from community

Ensemble Sensitivity Theory

Sensitivity of a metric to initial conditions is given by (Ancell & Hakim 2007):

$$\left[\frac{\partial J}{\partial x_o}\right]^T = \frac{\{\partial J \partial x_o\}}{\{\partial x_o \partial x_o^T\}} = A^{-1}\{\partial J \partial x_o\} = \frac{\mathrm{cov}(J, x_o)}{\mathrm{cov}(x_o, x_o)}$$

This can be used to calculate the variance of the metric:

$$\sigma = \left[\frac{\partial J}{\partial x_o}\right]^T A \left[\frac{\partial J}{\partial x_o}\right]$$

Ensemble Square Root Filter

$$x^a = x^b + K(y_o - Hx_b)$$

$$x'^a = (I - \alpha KH)x'^b$$

$$\alpha = \left(1 + \sqrt{\frac{R}{HP^b H + R}}\right)^{-1}$$

$$K = P^b H^T (HP^P H^T + R)^{-1}$$

K: Kalman Gain
R: Observation Error
P: Background Error Covariance
H: Observation Operator
See Whitaker and Hamill 2002