The Antarctic Radiosonde Network: Optimal Locations for Weather Observation

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Challenges for Radiosondes in Antarctica

- Current network is sparse - is coverage sufficient?
- Radiosondes serve many purposes simultaneously - NWP, scientific studies, etc.
- Getting data can be difficult
- Given limited resources and many objectives, where should radiosondes be located?
Can the information by these radiosondes be recovered by a handful of obs at other locations?

John Cassano “Climate of Extremes” chapter from *Antarctica: Global Science from a Frozen Continent* 2013/Matt Lazzara AMRC
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Optimizing for Radiosondes
Algorithmic Approach

Choose metric that describes the system and obtain a reference distribution for the metric.

Calculate the changes in the measure (total variance) for all possible new measurement locations.

The optimal measurement is one that maximizes the measure.

Incorporate the optimal measurement, and update the metric and state statistics appropriately.

Repeat steps 2-4 until desired number of stations are reached.
Optimal Network Design
Theoretical Background

Multivariate Variance Reduction

Optimal location is the one that maximizes the trace of

$$\delta \Sigma_J = DJ^T(A^' - A)DJ$$

Using the Ensemble Kalman Filter:

$$\delta \Sigma_J = -\frac{1}{E} \left[ DJ^T AH^T \right] \left[ DJ^T AH^T \right]^T$$

$$DJ^T AH^T = \{ \delta J(H\delta x)^T \}$$

Hryniw and Hakim 2015

- Optimizes for many metrics simultaneously
- No explicit calculation of covariances
Use a Monte Carlo bootstrap approach (1000 iterations)

- Draw random ensemble members (250) from the data to calculate metric and state statistics

- Use the square root form of the Ensemble Kalman Filter (EnKF) to calculate impact

- Square root EnKF allows sequential assimilation - station 1 is chosen, statistics updated, then station 2 is chosen conditional on station 1

\[ \delta x'_{n+1} = \delta x'_n - KH\delta x'_n \] perturbation update
Experimental Setup

Data

- Archived forecasts from the Antarctic Mesoscale Prediction System (AMPS) (Powers et al. 2011)
- Temperature data on the 15km full continental grid
- Metric is temperature at every 20th gridpoint horizontally and every 50hPa from 600hPa to 50 hPa
- Every 10th gridpoint is considered for an observation
- Data is at 00Z from Oct 1 2008 - Sept 31 2012
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Results
Optimal Network for Monitoring 00Z Tropospheric Temperature

Optimal Sounding Network for Tropospheric Whole Continent Temperature

Station 1

Station 2

58.68% of variance

2.16% of variance

Station 3

3.39% of variance

Change in Variance

Station
Results
Optimal Network for Monitoring 00Z Tropospheric Temperature, without influence of current radiosondes
Results
Optimal Network for Reducing 12hr Surface Temperature Forecast Errors

Optimal Sounding Network for T2m 12h Whole Continent Forecast Errors

Station 1
23.84% of variance

Station 2
2.29% of variance

Station 3
2.11% of variance

Change in Variance

Station
Results
Optimal Network for Reducing 24hr Surface Temperature Forecast Errors

Optimal Sounding Network for T2m 24h Whole Continent Forecast Errors

Station 1
20.92% of variance

Station 2
2.07% of variance

Station 3
1.92% of variance

Change in Variance

Δ^2
0
200
400
600
800
1000
1200
1400
1600

Station
1
2
3
4
5
Results
Optimal Network for Reducing 36hr Surface Temperature Forecast Errors

Optimal Sounding Network for T2m 36h Whole Continent Forecast Errors

Station 1

Station 2

Station 3

Change in Variance

% frequency

δ^2

Station
Conclusions and Future Work

**Conclusions**

- Current radiosonde network explains much of tropospheric variance
- However some gaps exist and current stations could be in better locations
- Coastal locations seem more important for forecasting, and interior for observation

**Next Steps**

- OSEs with currently assimilated radiosondes in AMPS
- Optimal locations for full tropospheric forecast errors
- Optimize for other fields such as geopotential height and wind speed

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