Evaluating the optimal level and mix of public investment in observations for weather prediction: 
An economic approach

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[Morss, Miller, and Vasil (MWR, in press)]
Motivation

- Evaluating benefits and costs of different configurations of the observing network (and prediction system)
  - is a major goal of THORPEX
  - has been discussed since the first Global Atmospheric Research Program
- Such evaluations help motivate implementation of proposed modifications and guide system design
- But the meteorological community still lacks a systematic framework for analyzing this issue
Motivation

• International THORPEX Science Plan, Executive Summary:

This research will identify and assess the societal/economic costs and benefits of THORPEX recommendations for implementing interactive forecast systems and improvements in the global observing system.
Motivation

• 1967 WMO report on “Design of Optimum Networks for Aerological Observing Stations”, Forward:

  Meteorologists have long been in doubt about the optimum density, in both time and space, of observations of the different meteorological parameters for various meteorological functions ...

  ... a realistic balance between inadequate data and an unnecessarily dense network ...
Goals

- Using standard economic theory, develop a framework for analyzing:
  - Optimal level of forecast skill (level of public investment in observations for weather prediction)
  - Optimal level/mix of observations to use in producing that level of forecast skill
    (Builds off work of Zillman/Freebairn)
- Illustrate the framework using an example
Economic approach

• Criterion: Maximize economic efficiency
  Allocate resources in a way that maximizes net economic benefit = benefits – costs
• Forecasts = economic output → benefits
• Observations = input to forecast production → costs

• Note
  – Standard benefit-cost analysis can be considered a subset of the framework
  – Economic analysis is one input to policy decisions
Total Benefit ($TB$) & Total Cost ($TC$)

$FC = \text{Fixed Cost}$

$q_{opt} = \text{optimal level of output}$

level of output ($q$)

(forecast skill)
Net Benefit \((NB = \text{Total Benefit} - \text{Total Cost})\)

- \(q_{opt}\) = optimal level of output
- \(q_{opt}\) = maximum \(NB\)
- set \(dNB/dq = 0\)
- \(d(TB-TC)/dq = 0\)
- \(MB - MC = 0\)
- \(MB = MC\)
Marginal Benefit ($MB$) & Marginal Cost ($MC$)

$q_{opt} = \text{optimal level of output} = \text{maximum NB}$

set $dNB/dq = 0$
$d(TB-TC)/dq = 0$
$MB - MC = 0$
$MB = MC$
Production function underlies cost function

(variable cost = cost of variable input used in production)
Can use production function to derive criterion for optimal level of input
Two-dimensional production function

Can use production function to derive criterion for optimal mix of inputs
Illustration of framework: Example

- Derive *one-input production function* from Observing System Simulation Experiments (OSSEs), based on results in Morss, Emanuel, and Snyder (*JAS*, 2001)
  - Quasi-geostrophic (QG) channel model on a β-plane, 250km grid spacing
  - Simulated radiosonde-like observations (vertical profiles of wind and temperature)
  - 3-dimensional variational (3DVAR) data assimilation system
Illustration of framework: Example

• Derive *cost curves* by combining production function with the estimated cost of adding a U.S. radiosonde observation

• Derive *benefit curves* from estimates of non-market value of daily forecasts to U.S. households (from Stratus Consulting 2002)

• Analyze results to derive
  – Economically optimal level of forecast skill
  – Economically optimal level of radiosonde-like observations
Example: Production function
Example: Marginal Cost

Marginal Cost

\(\Delta\) annual dollars per unit forecast skill

\(S\): forecast skill

\(MC_1\)

\(MC_2\)
Example: Optimal level of production
Example: Optimal level of observations

Total Product

normalized 1-day forecast skill ($S$)

number of sounding sites ($N$)

$q_{opt}$

$N_{opt}$
Knowledge gaps

To implement a more complete evaluation, need:

1) Improved production function, with multiple variable inputs

2) Improved estimates of the incremental cost of adding different types of observations

3) Improved estimates of the marginal benefit of improving weather forecasts

4) Forecast verification norms that facilitate connecting the production function with societal benefit
Summary

- Economics of observing network (and forecasting system) is of interest
- Study presents and illustrates framework for evaluating economically optimal public-sector level of forecast production and mix of observations
- Results identify gaps in existing knowledge
- Framework can also be applied to evaluate public investments in other components of weather prediction system, including trade-offs
- Future work
Questions?