RAND HEALTH

Evaluation of DC Department of Health's Syndromic Surveillance System: Fine-Tuning Statistical Detection Algorithms

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Quantitative Methods in Defense and National Security
George Mason University, February 2007

Outline

- Background and rationale
- Detection algorithms
- DC Data
- Fine-tuning approach
- Results
- Implications and next steps

Background

- Syndromic surveillance (SS) involves collection and analysis of syndrome-related data to detect a change or trend in health of a population
  - E.g., outbreak detection, beginning of the flu season
- Systems closely monitor daily counts of key symptom groups
- Statistical detection algorithms determine when counts are higher than normal
  - Flag/alarm when no longer under the null distribution (e.g., when outbreak)

Rationale

- Problem: little attention given to parameters in statistical detection algorithms
  - CDC-EARS – various parameters without user control
  - CUSUM – k
  - CUSUM EXPO – k, λ
- Choices can strongly affect statistical performance
  - sensitivity, false positive rate, timeliness
- Goals:
  - Identify optimal values of parameters for CUSUM, CUSUM EXPO, and MV CUSUM
  - Determine which algorithm is most effective

Detection algorithms

- CUSUM (CUmulative SUMmation)
  - $C_t = \max [C_{t-1} + (y_t - \mu) - k, 0]$ Alarm if $C_t > h$
- CUSUM EXPO (mean-adjusted)
  - Exponentially Weighted Moving Average (EWMA)
    - $z_t = \lambda y_t + (1-\lambda) z_{t-1}$
  - $C_t = \max [C_{t-1} + (y_t - z_t) - k, 0]$ Alarm if $C_t > h$
- Multivariate (MV) CUSUM (Stoto et al., 2006)

DC's DOH S.S. System

- Emergency Room Syndromic Surveillance System
  - Since 9/12/01, DC DOH has collected data on a daily basis from hospital ERs
  - Part of regional surveillance system including suburban Maryland and Northern Virginia
  - Data for this presentation through 5/20/04 (980 days)
- 9 hospitals report number of patients with particular chief complaint
  - Respiratory
  - Gastrointestinal
  - Unspecified infection
  - Rash
  - Neurological
  - Sepsis
  - Death
  - Other

Fine-tuning approach

- Two-pronged approach:

  1. Simulation study and ROC curves
     - Determines parameters with optimal balance between false positive rates and sensitivity

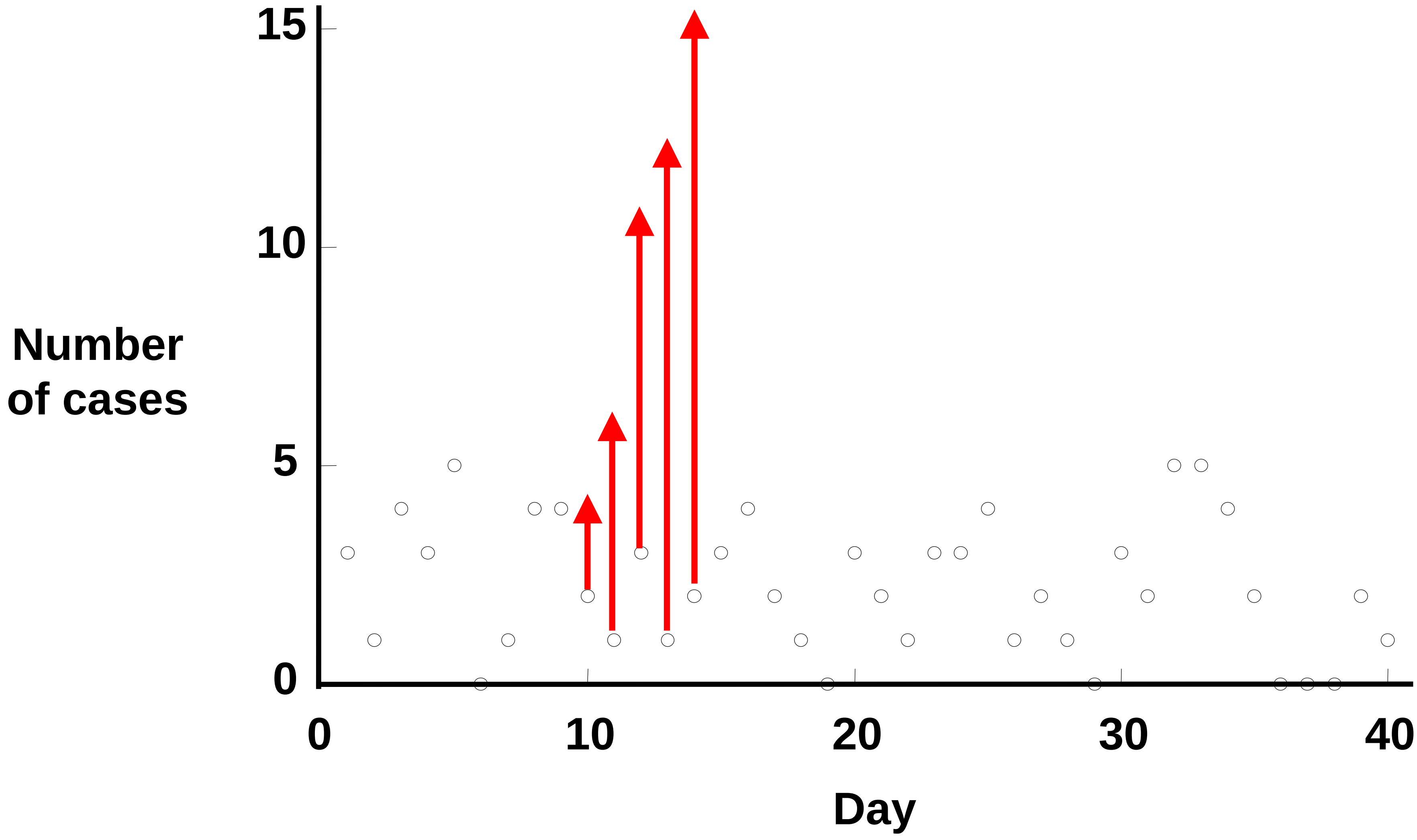
  2. Explore impact of choices against “known” outbreaks
     - Measures sensitivity and timeliness

Simulation study

- Simulated linearly increasing outbreaks
  - Inserted x, 2x, 3x, …extra cases on each subsequent day of outbreak
- Day 1 of outbreak placed on each day between 9/12/01 to 5/8/04
  - 970 different data sets with a simulated outbreak
- Computed sensitivity of algorithm to detect outbreak by day 3 in the non-flu season

$$Sensitivity = \frac{\#\ flags\ \ by\ \ day\ \ 3}{length\ \ of\ \ nonflu\ \ season}$$

Simulated outbreaks



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Fine-tuning CUSUM parameter

- CUSUM (CUmulative SUMmation)
  - $C_t = \max [C_{t-1} + (y_t - \mu) - k, 0]$ Alarm if $C_t > h$

- Fine-tuned k using two-pronged approached
  1. ROC curve approach
  2. Check against "known" outbreaks

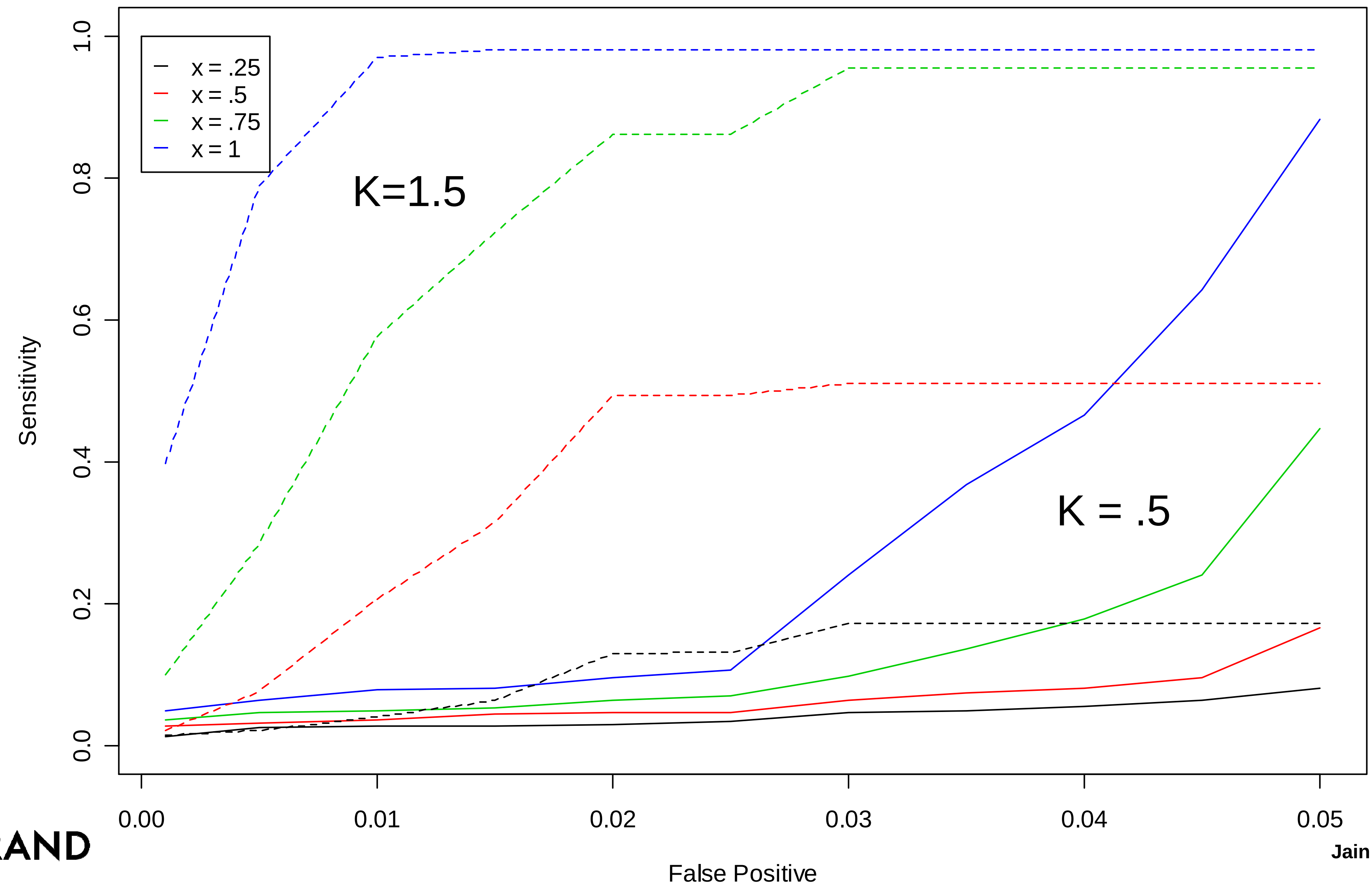
- Results:
  - k = 1.5 works better for hospitals with smaller absolute average count (< 5)
  - k = 0.5 works better for larger absolute average count ($\geq$ 5)

Background rates (non-flu season)

Mean # of daily cases (non-flu)	**Hospital H**	**Hospital A**	**Hospital I**
Unspecified Infection	3.48	4.81	28.11
Gastro-intestinal	8.96	21.92	14.67

H, Unspecified (3.5)

ROC Curves for Detection by Day 3 in the Non-Flu Season: Hospital H and Unspecified Infection



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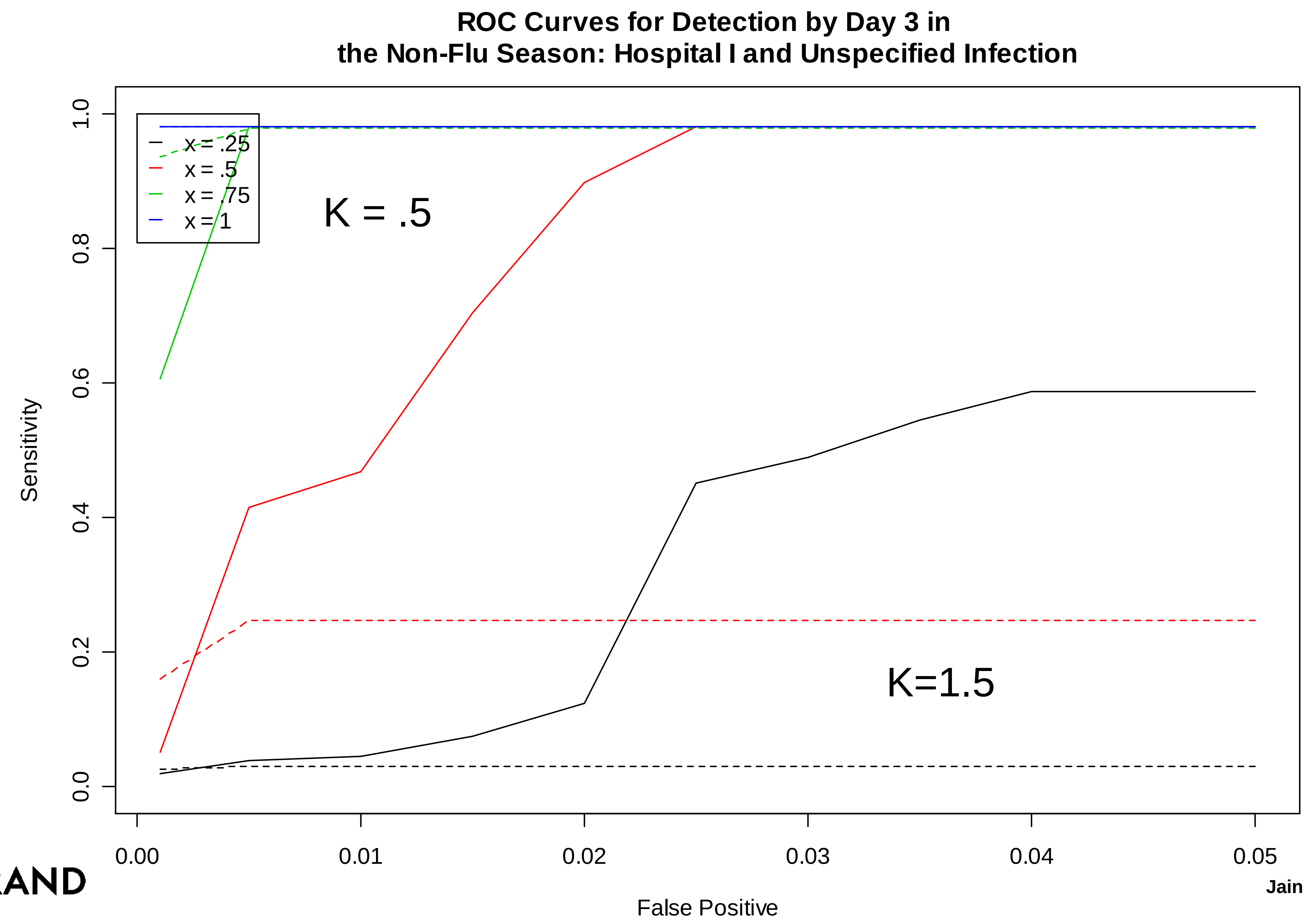
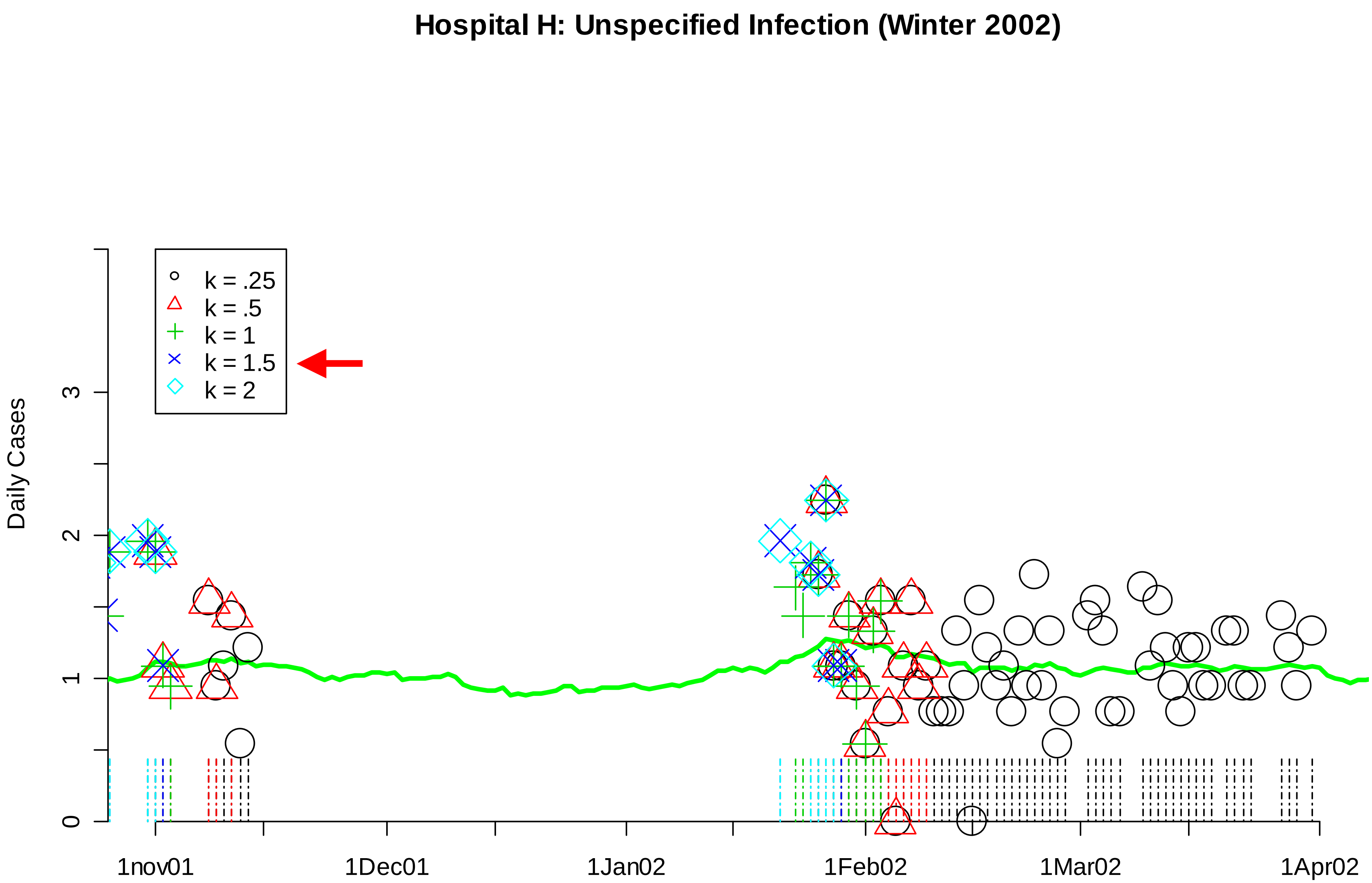
I, Unspecified (28.1)



H, Unspecified, ‘02 (3.5)



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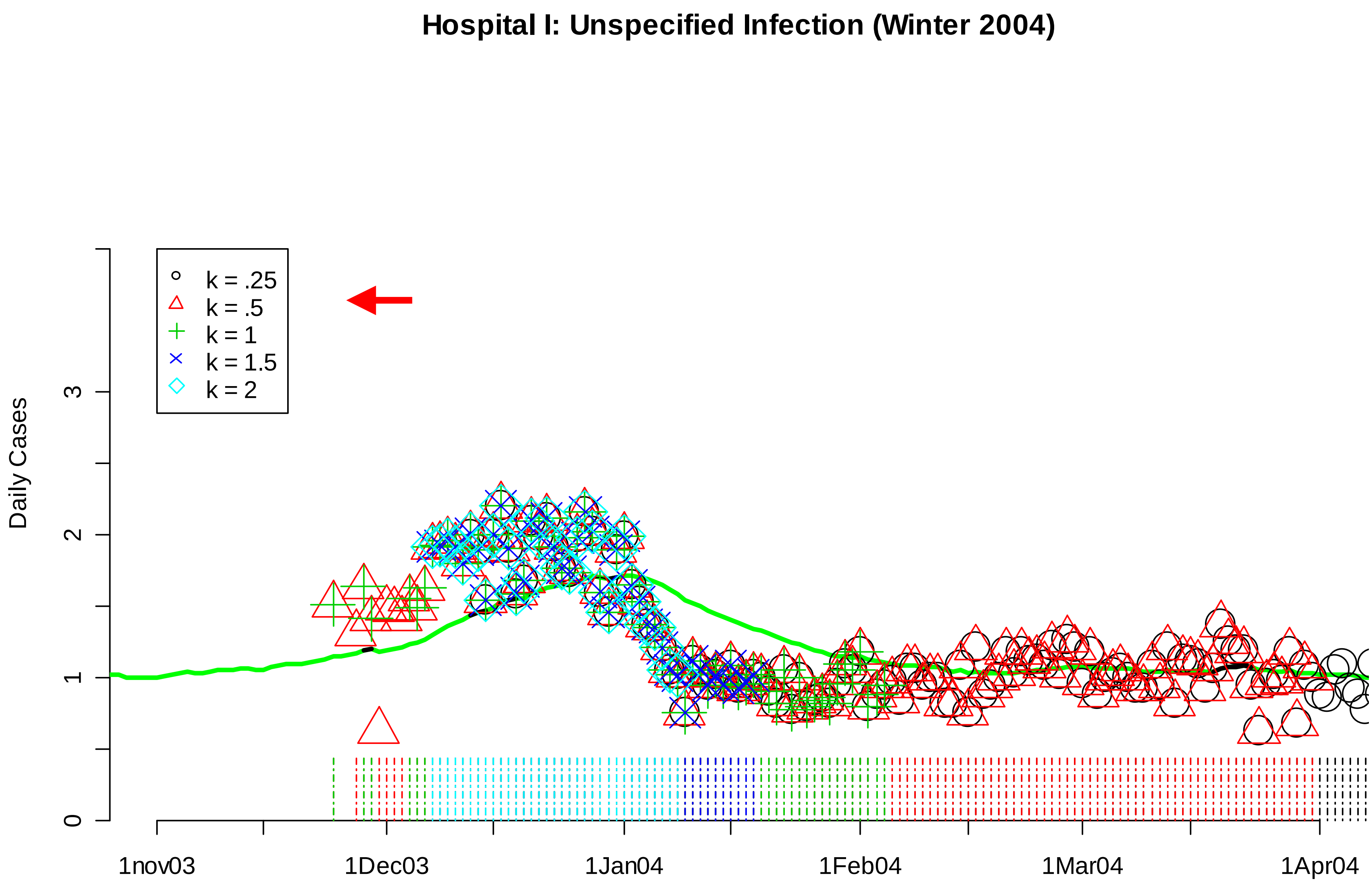
I, Unspecified, '04 (28.1)



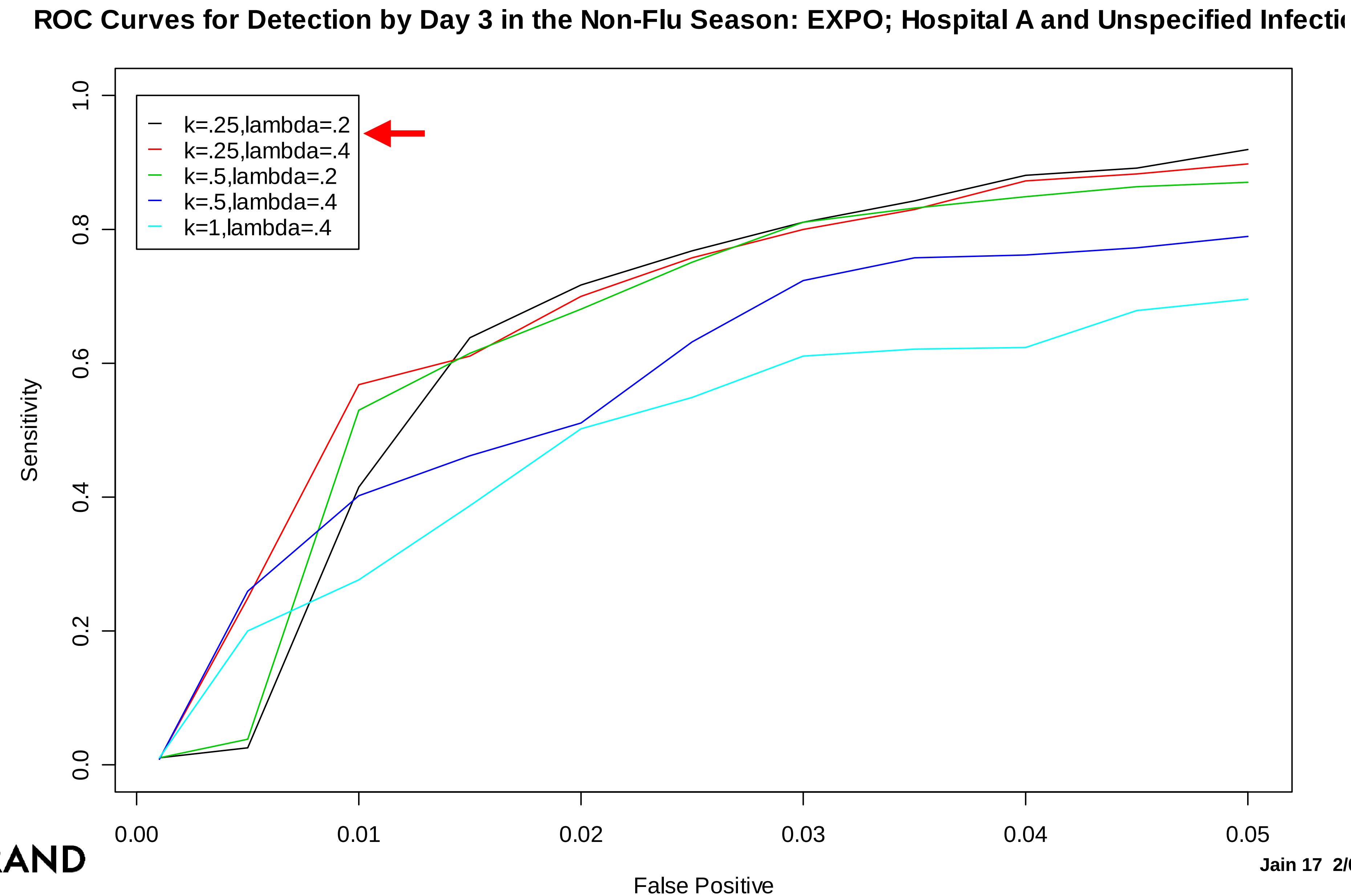
Fine-tuning EXPO parameters

- CUSUM EXPO (mean-adjusted)
  - EWMA $z_t = \lambda y_t + (1-\lambda)z_{t-1}$
  - $C_t = \max [C_{t-1} + (y_t - z_t) - k, 0]$ Alarm if $C_t > h$

- Fine-tuned (k, λ) using two-pronged approached.
  1. ROC curve approach
  2. Check against "known" outbreaks

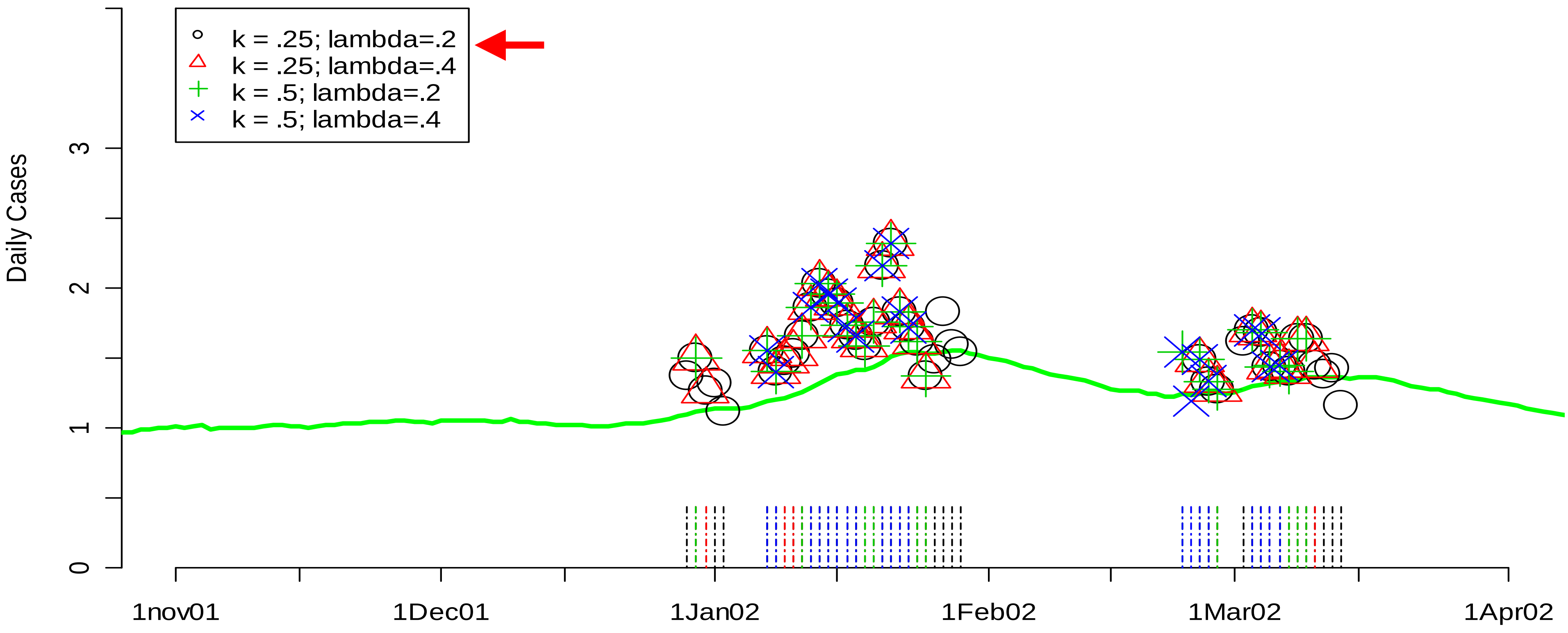
- Results:
  - k=0.25, $\lambda = 0.4$ or 0.2 works reasonably well across the board
  - Less distinction between the better combos

A, Unspecified (4.8)



I, Unspecified, '02 (28.1)

Hospital I: Unspecified Infection; 28.1 (Winter 2002)



Fine-tuning MV CUSUM parameters

- Fine-tuned k using two-pronged approached.
  1. ROC curve approach
  2. Check against “known” outbreaks

- Results:
  - k = 7 works reasonably well across the board for 3 data streams
  - Larger value (k = 9) needed for 6 data streams

Comparing the algorithms

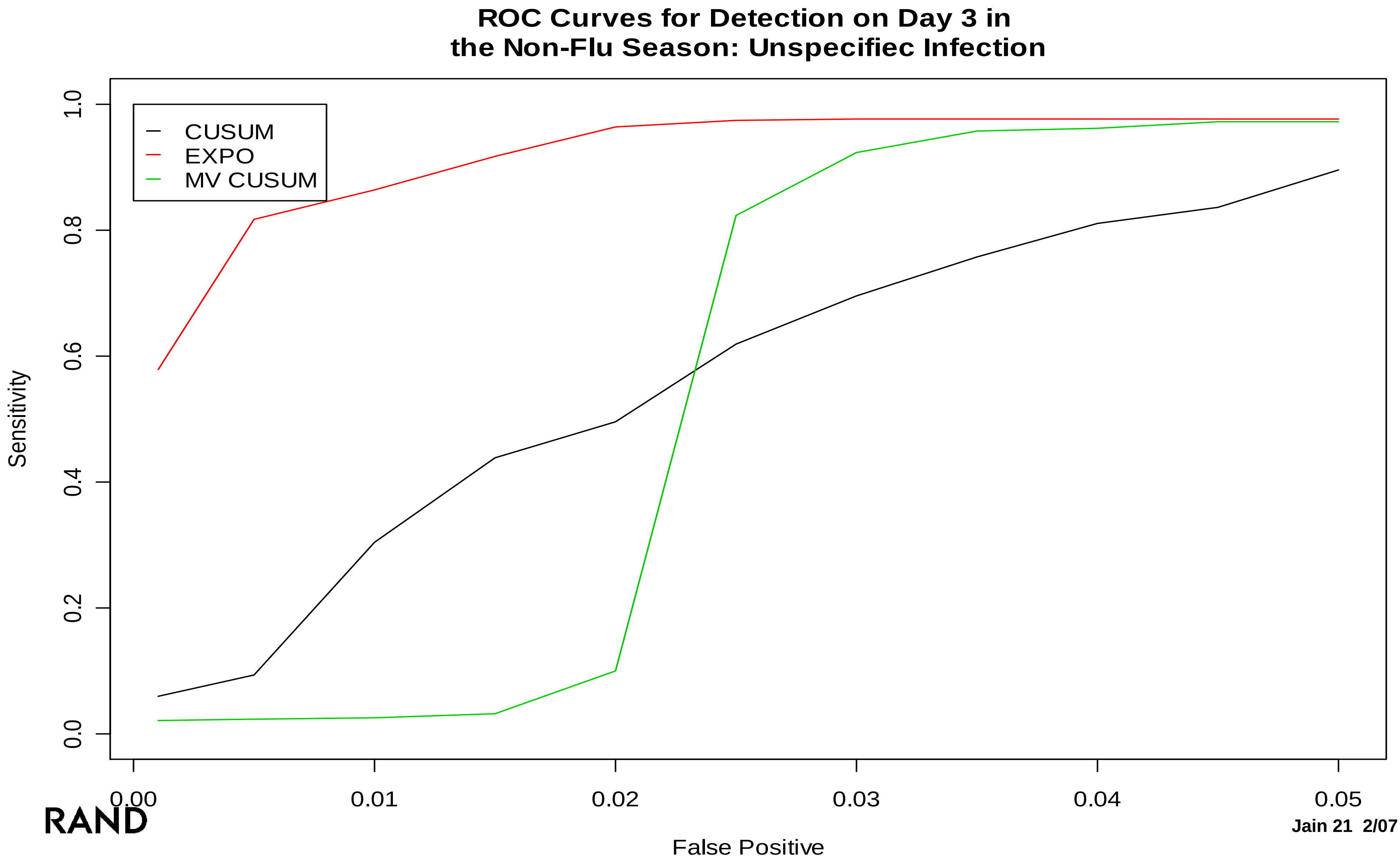
- Compare fine-tuned CUSUM, CUSUM EXPO, and MV CUSUM algorithms using 2-pronged approach

- Adjust FP rates to account for multiple streams in extensions of univariate CUSUM and CUSUM EXPO to >1 stream

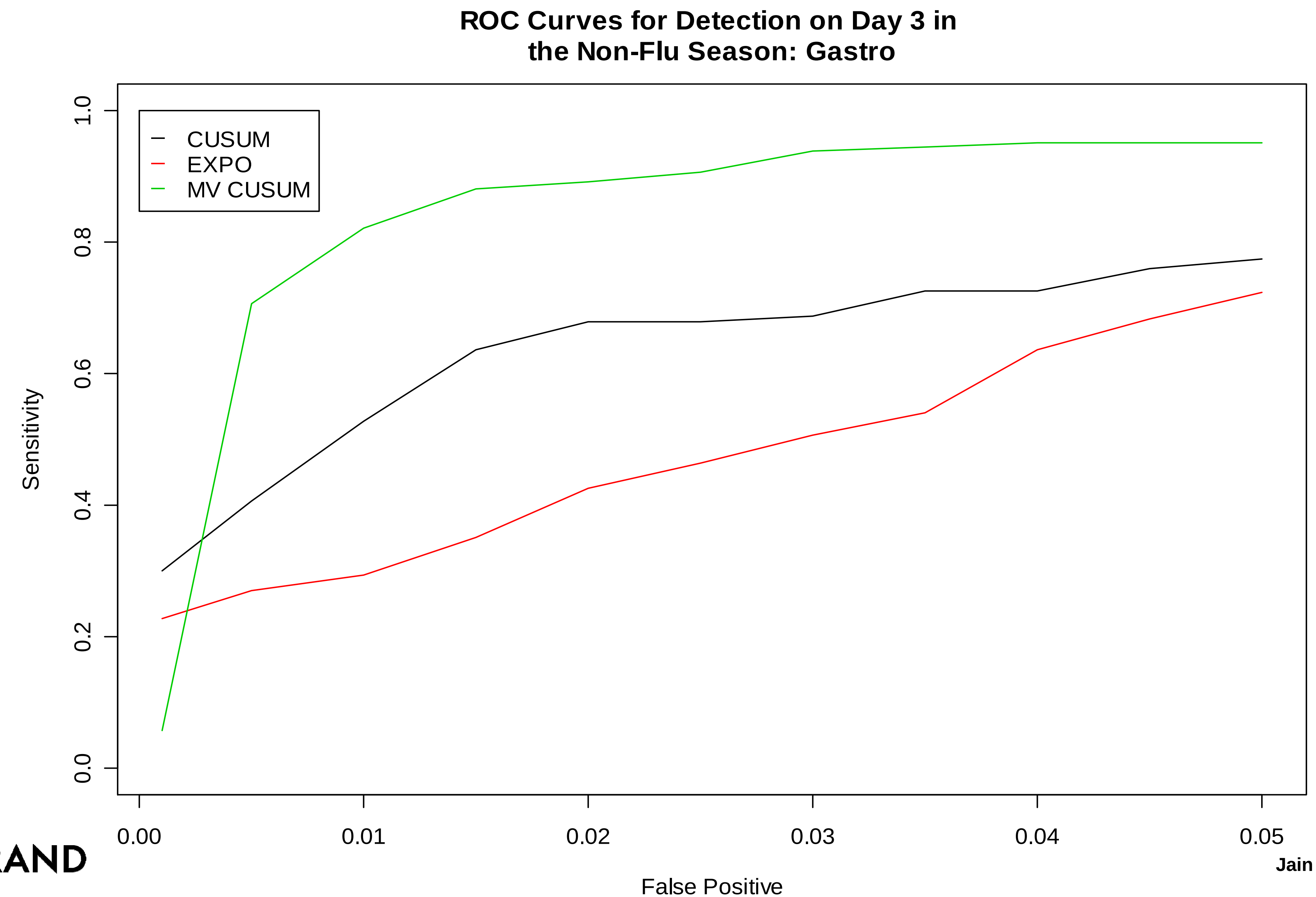
- Results: In general, MV CUSUM performs better than CUSUM and CUSUM EXPO

- In one setting (simulation study using 3 streams of unspecified infection), EXPO outperformed MV CUSUM

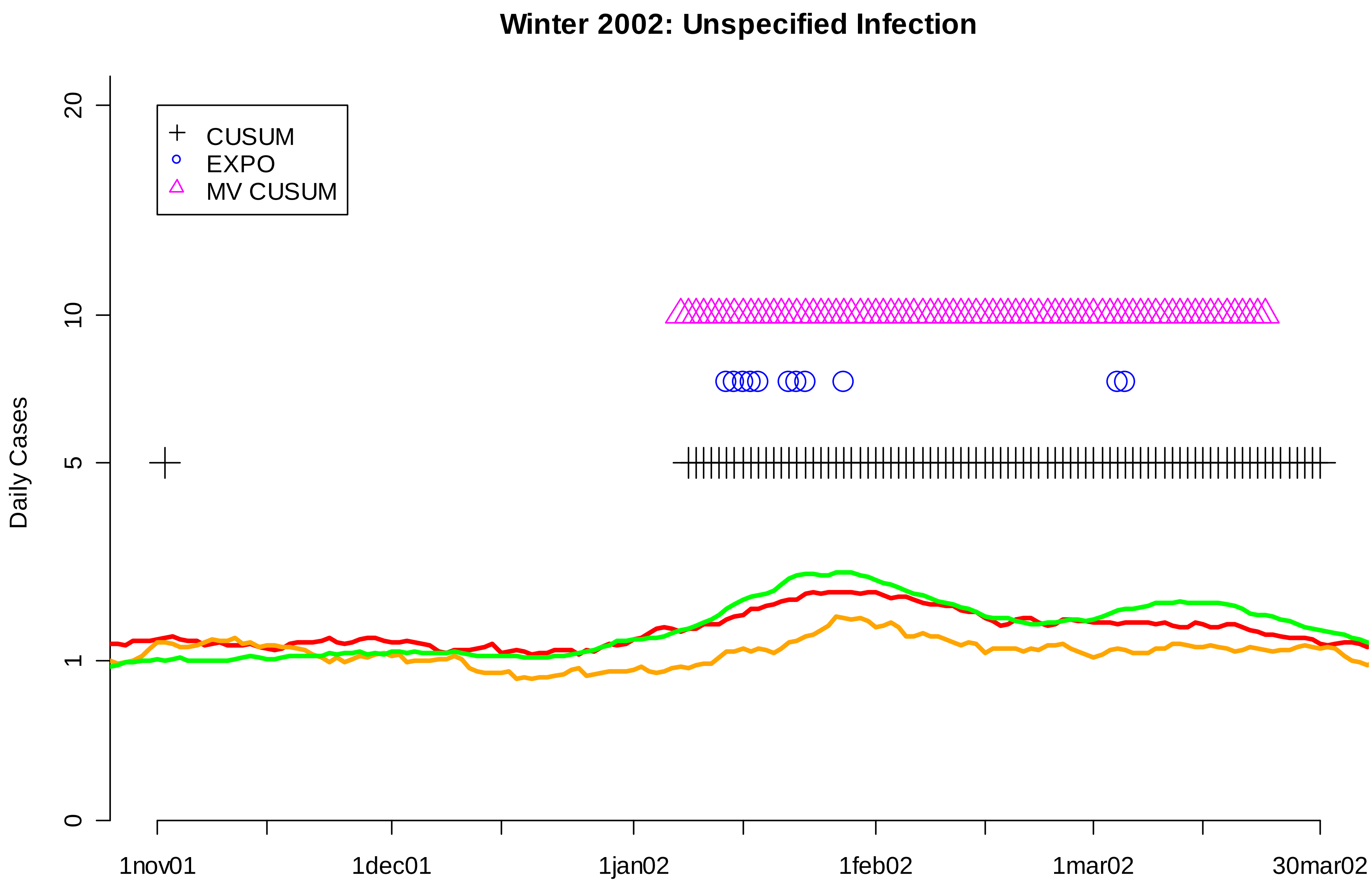
Unspecified Infection (3 streams)



Gastro (3 streams)



Winter 2002: Unspecified Infection



Red = Hospital A, Orange = Hospital H, Green = Hospital I

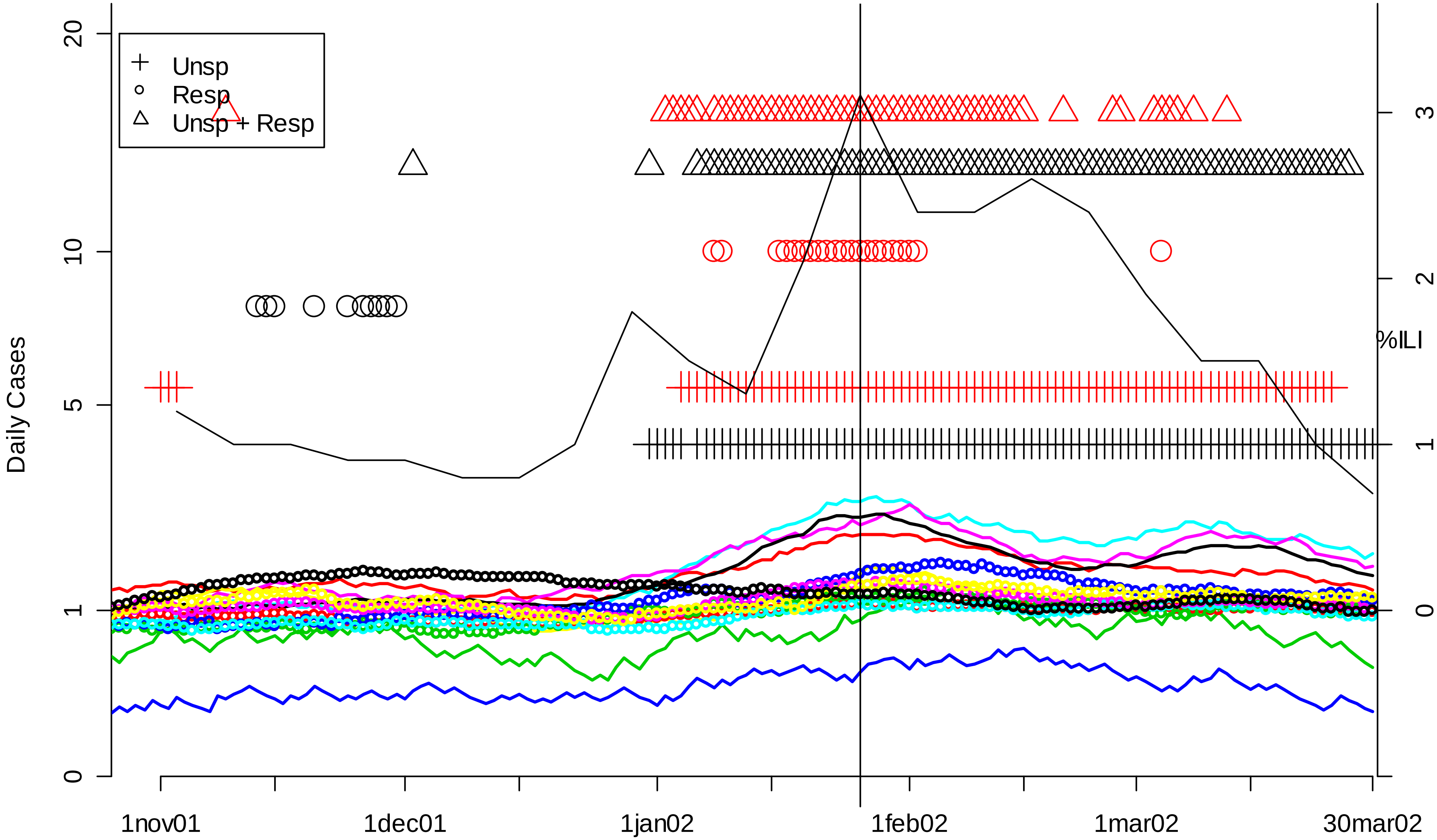
Conclusions

- Detection algorithms parameter values matter
- Found parameter values that perform well in our data
  - Results sensitive to distribution of data (esp. MV CUSUM)
- Recommend practitioners take time to fine-tune
  - Need software to make implementation easier
    - E.g., add fine-tuning option to CDC's EARS
- Implications for DC DOH:
  - Fine-tuned parameters more likely to pick up on beginning of the flu season
  - Advantage to using MV algorithms such as MV-CUSUM

Next Steps

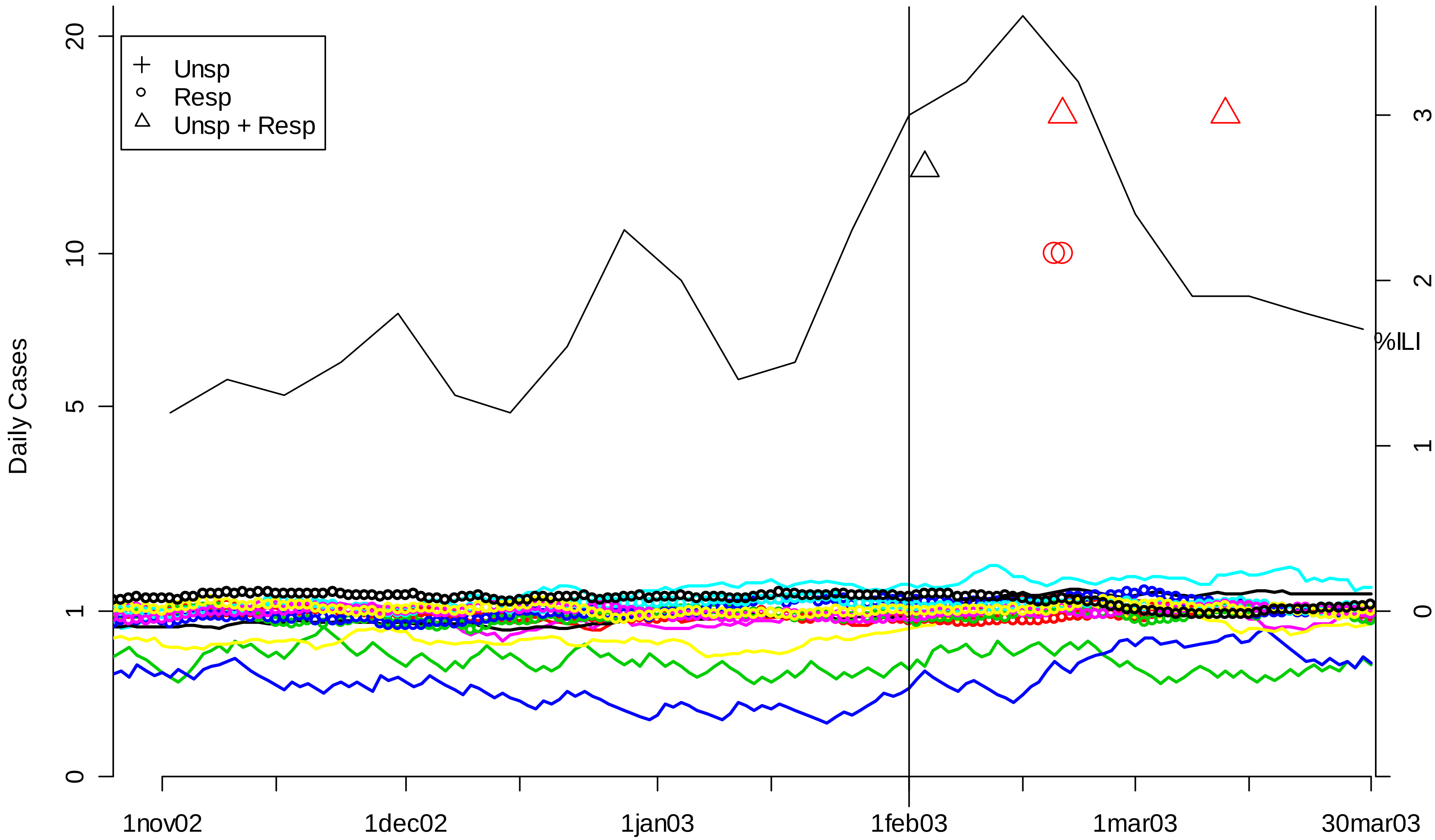
- Evaluate detection algorithms on other data streams
  - Ideally there would be known ‘outbreaks’
- Program detection algorithms and the ability to manipulate associated parameters into a user-friendly software package
- Prospectively test algorithms and their ability to detect the start of the flu season with other data sources

Winter 2002: Unspecified and Respiratory and CDC Sentinel Physicians



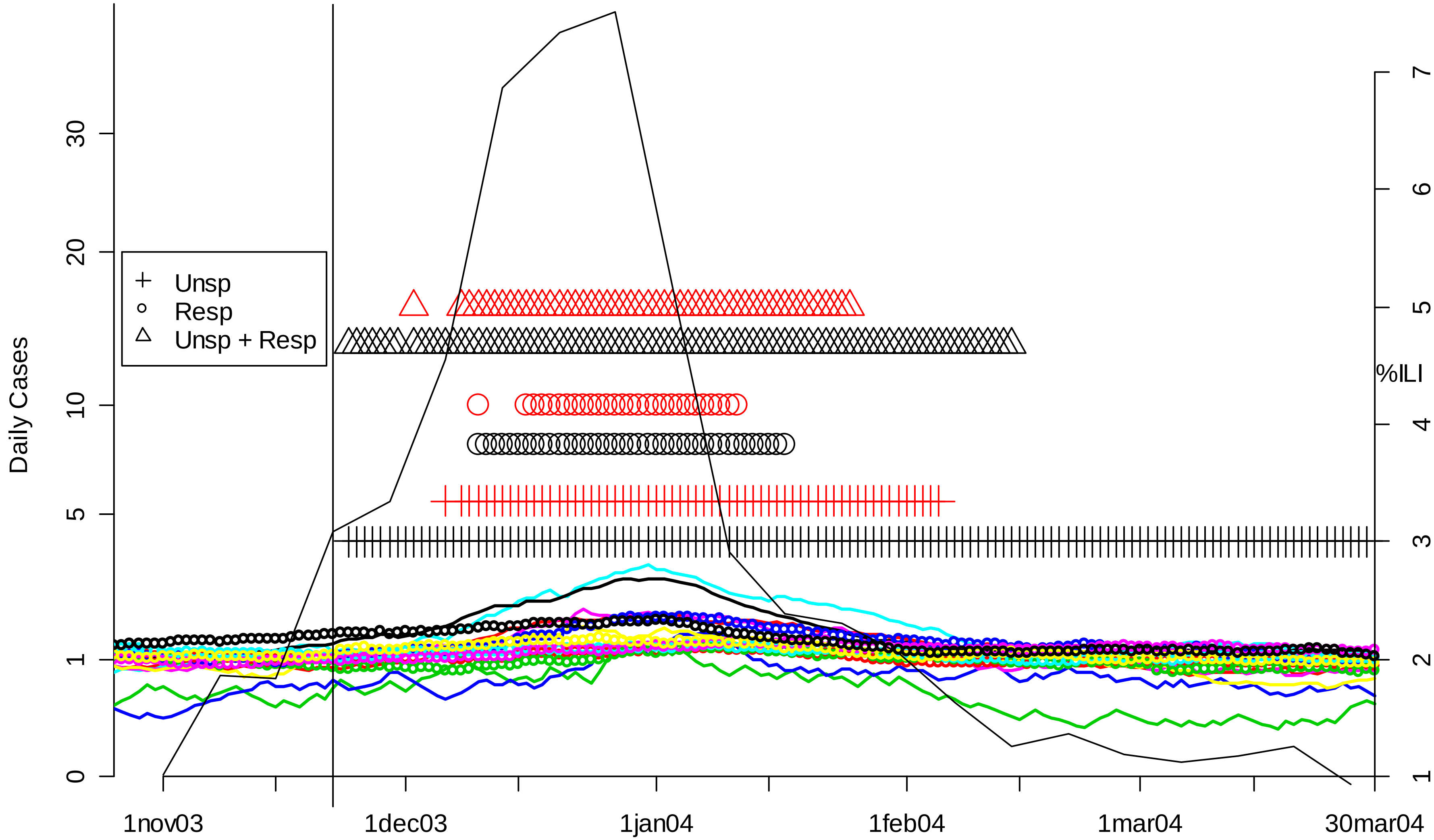
Solid lines = Unsp; Dotted lines = Resp; Red = Hospital A,Green = Hospital B,Blue = Hospital C,Lt. Blue= Hospital D,Purple = Hospital E,Yellow = Hospital H,Black = Hospital I

Winter 2003: Unspecified and Respiratory and CDC Sentinel Physicians



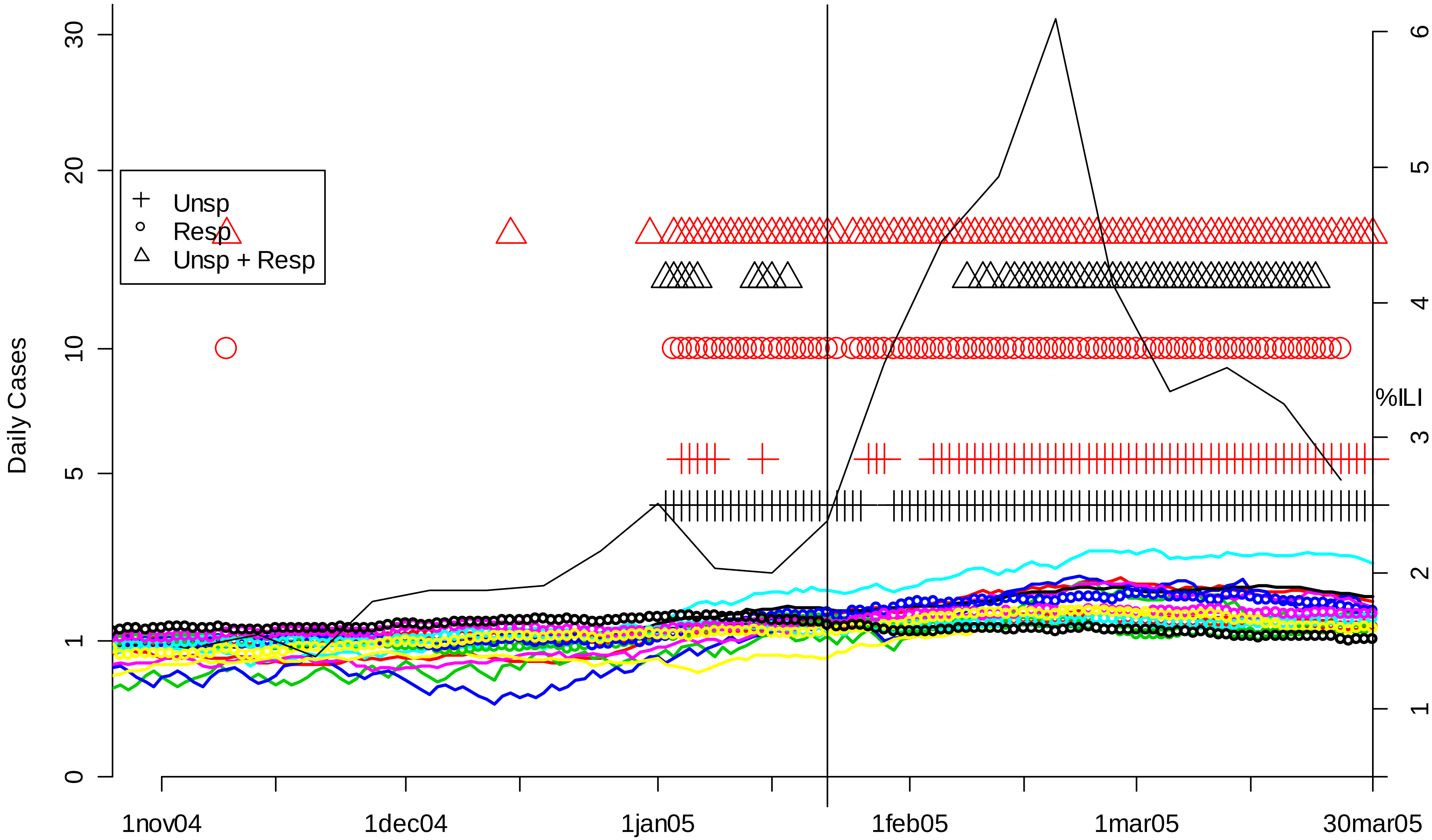
Solid lines = Unsp; Dotted lines = Resp; Red = Hospital A,Green = Hospital B,Blue = Hospital C,Lt. Blue= Hospital D,Purple = Hospital E,Yellow = Hospital H,Black = Hospital I

Winter 2004: Unspecified and Respiratory and CDC Sentinel Physicians



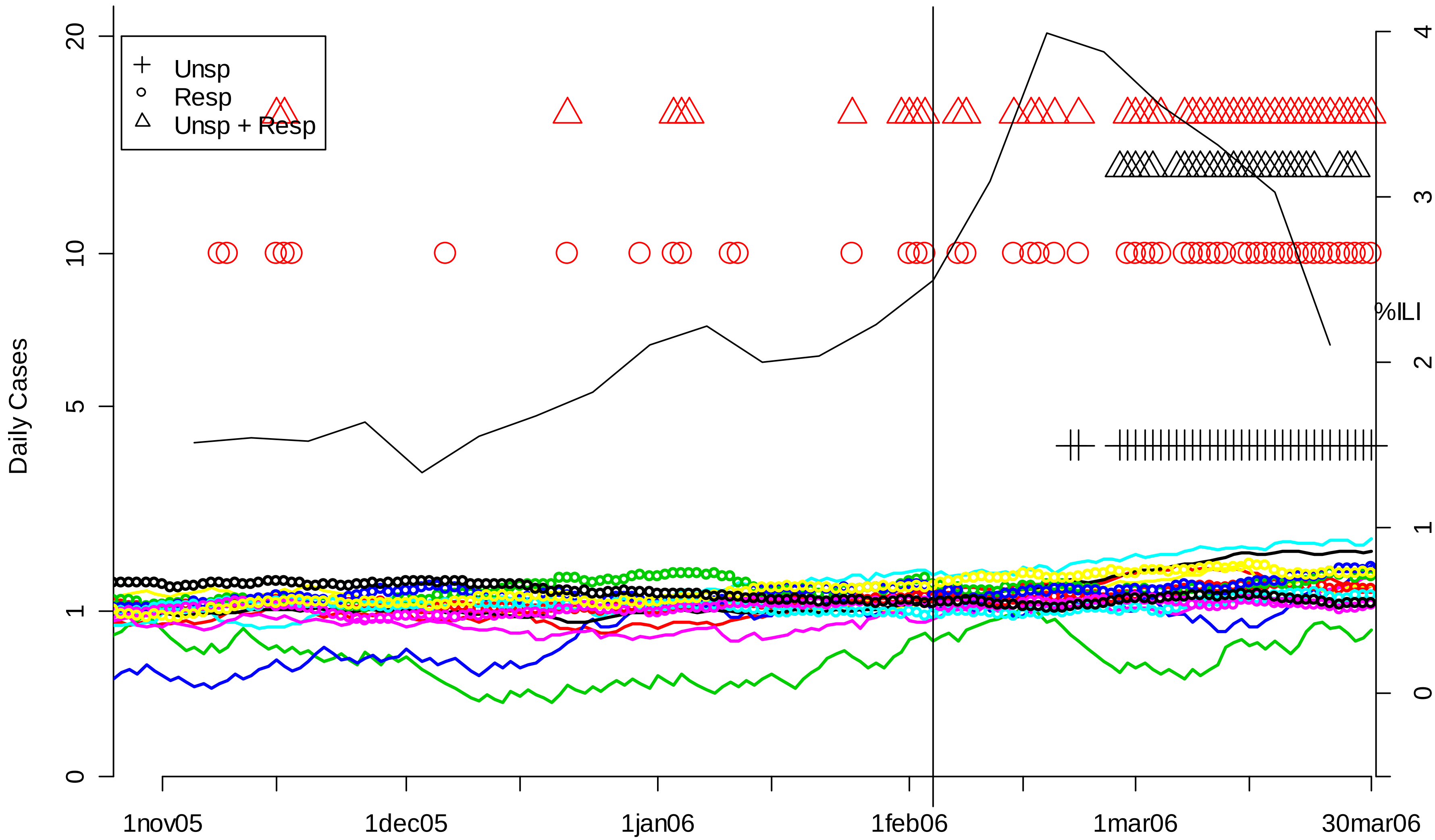
Solid lines = Unsp; Dotted lines = Resp; Red = Hospital A,Green = Hospital B,Blue = Hospital C,Lt. Blue= Hospital D,Purple = Hospital E,Yellow = Hospital H,Black = Hospital I

Winter 2005: Unspecified and Respiratory and CDC Sentinel Physicians



Solid lines = Unsp; Dotted lines = Resp; Red = Hospital A,Green = Hospital B,Blue = Hospital C,Lt. Blue= Hospital D,Purple = Hospital E,Yellow = Hospital H,Black = Hospital I

Winter 2006: Unspecified and Respiratory and CDC Sentinel Physicians



Solid lines = Unsp; Dotted lines = Resp; Red = Hospital A,Green = Hospital B,Blue = Hospital C,Lt. Blue= Hospital D,Purple = Hospital E,Yellow = Hospital H,Black = Hospital I

Early Detection of the Flu Season by DC ER Syndromic Surveillance

	2002	2004	2005	2006
CDC Sentinel physicians	Jan 26 +26	Nov 22	Jan 22 +20	Feb 4
DC Hospital I	Dec 31	Nov 24 +2	Jan 2	Feb 27 +23
All other DC hospitals	Jan 4 +4	Dec 8 +14	Jan 4 +2	--