Identifying the normal ranges of behavior in an agent-based epidemic model

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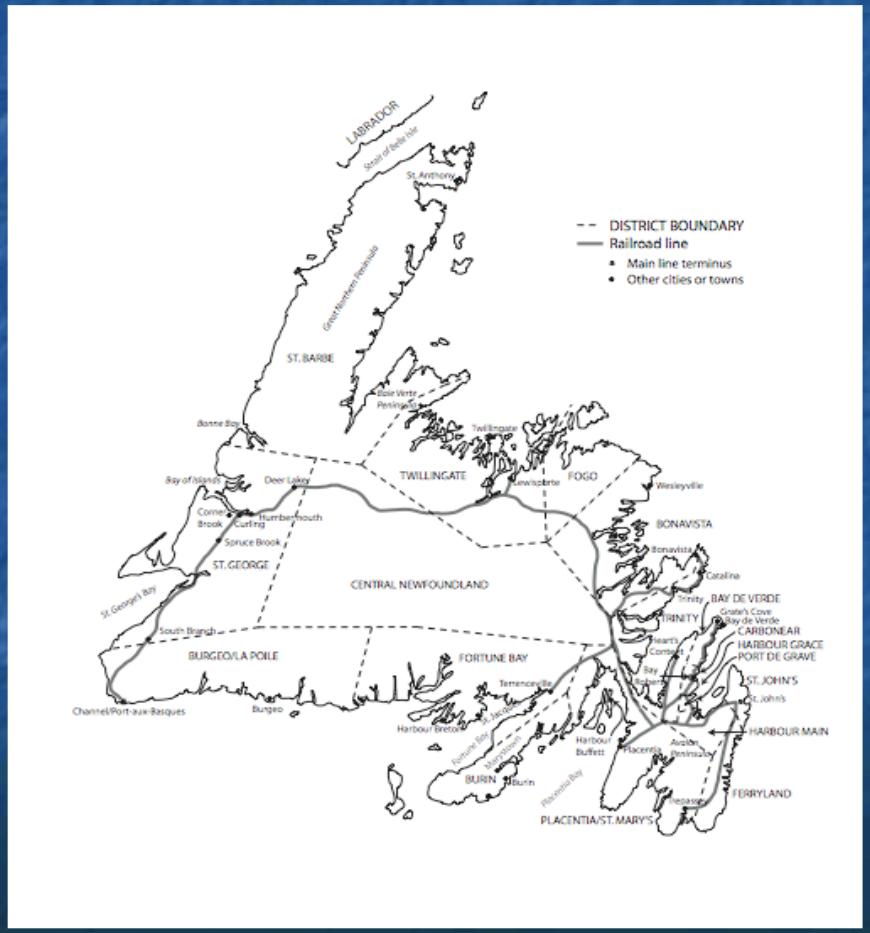
Some overarching research questions

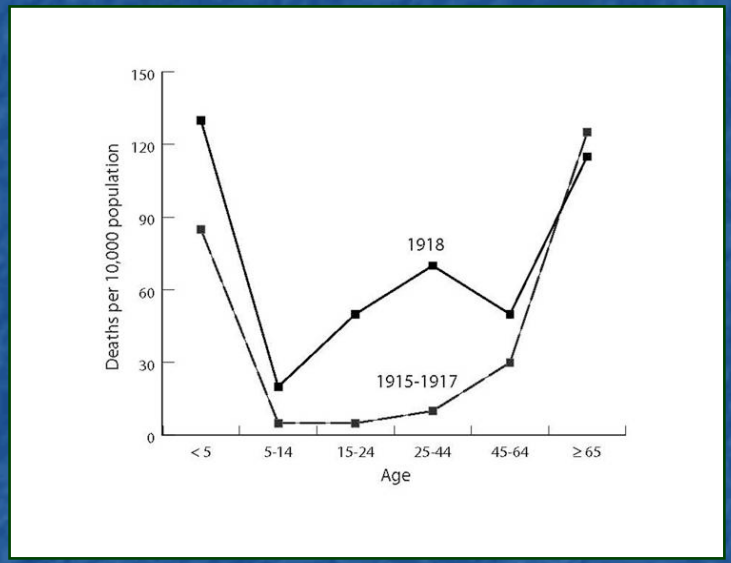
- How does the nature of social interactions within a small community influence infectious disease spread?
  - Impact of age and sex differences
  - Occupational differences
  - Household size and composition
  - Visiting patterns
- How might modern medical practices have influenced recent disease patterns in comparison with those of the past?
- How do the epidemic experiences of very small and dispersed communities (with their highly localized interactions) differ from those of large, urbanized communities?

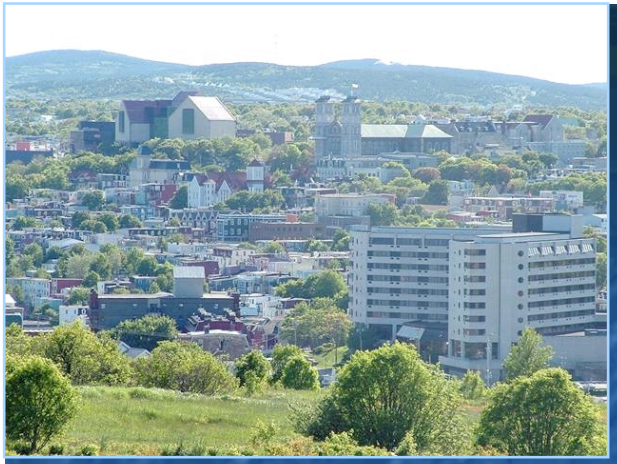
Newfoundland



General characteristics of the 1918 flu epidemic

- Total global mortality estimated at 50,000,000 or more
- Worldwide mortality rate averaged 2.5-5 deaths per 1000 population, but highly variable with a range of < 1 to nearly 800 deaths per 1000
- Global spread clearly associated with troop movements at the end of WWI
- Mortality high for all ages; young adults especially hard hit relative to other flu epidemics
- Some deaths due to influenza itself; many due to pneumonia or other secondary infections

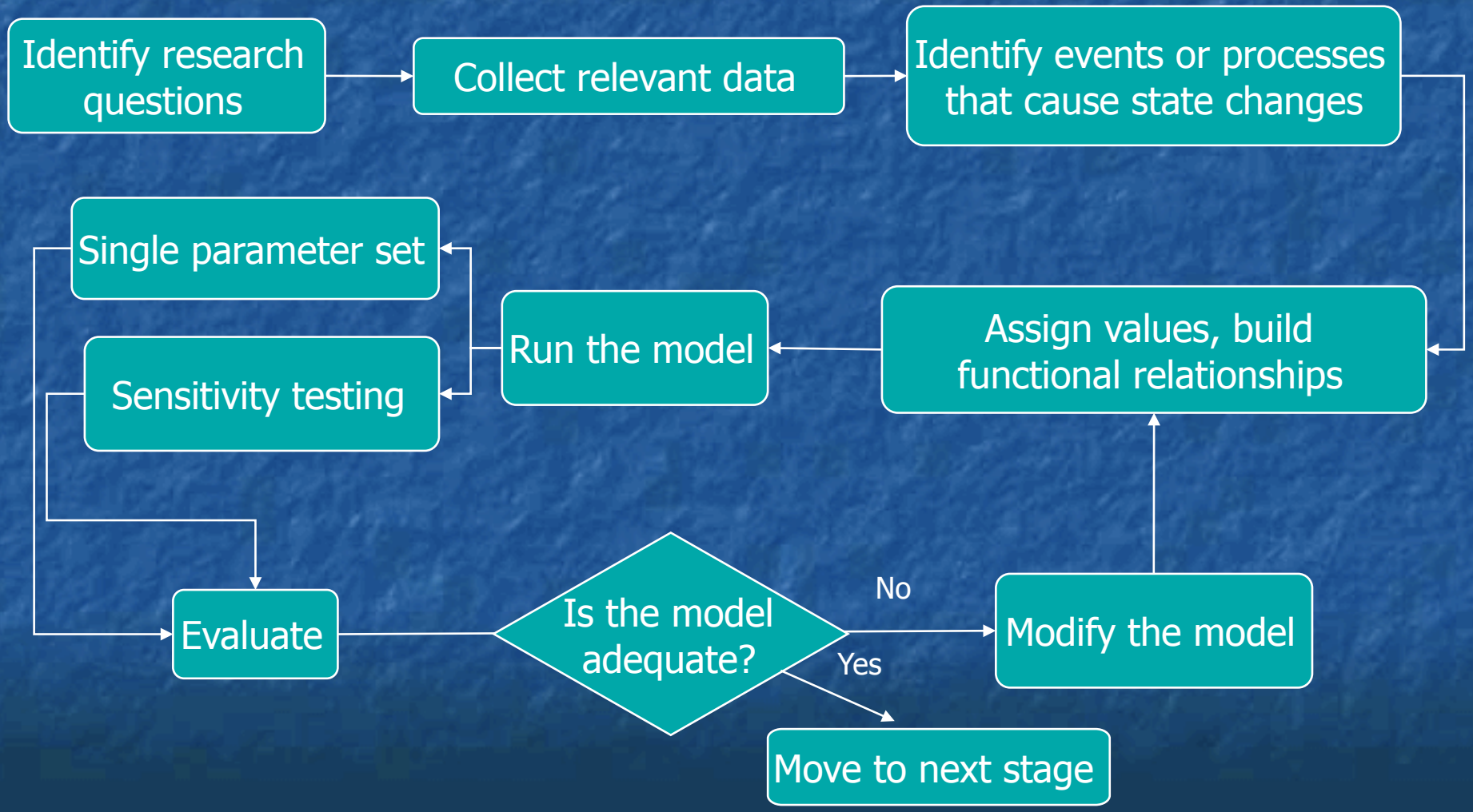




Data sources

- Death records for 1918-1920 from the provincial archives ("The Rooms")
  - Name, date of death, place of death, cause of death, birth date, birth place, sex, age, etc.
  - 1229 flu deaths, 825 deaths from pneumonia and related conditions
- Hospital records from the Charles S. Curtis Memorial Hospital in St. Anthony
- Census data and other vital statistics
- Newspaper accounts of the epidemic
- Government correspondence and other miscellaneous information

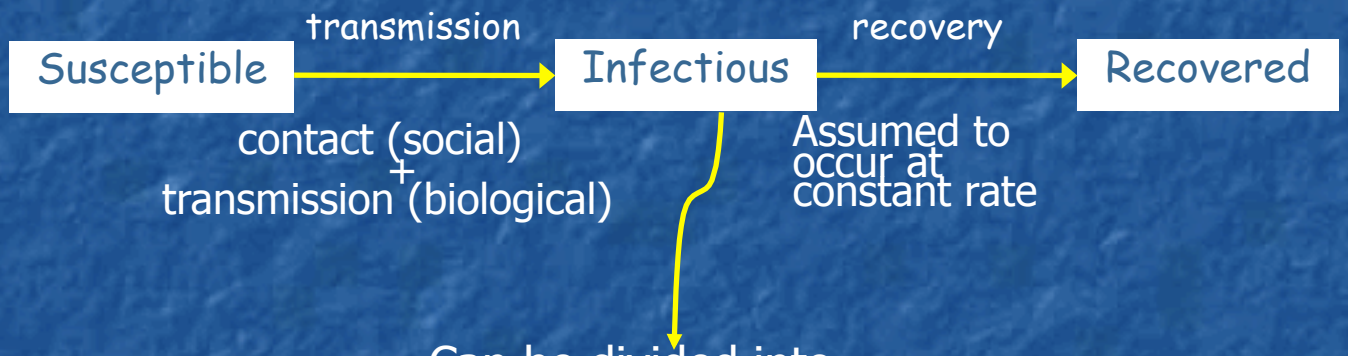
The Modeling Process



Why use a mathematical/computer model?

- Allow for "experimentation" on human populations that would be impossible or unethical in the real world.
- Help to understand conditions under which infectious diseases emerge and spread across a landscape.
- Focus research efforts on factors most likely to have a significant impact on patterns of epidemic spread.
- Identify critical areas with insufficient data.
- Can be used to evaluate the efficacy of potential control strategies before attempting costly and/or risky field trials.

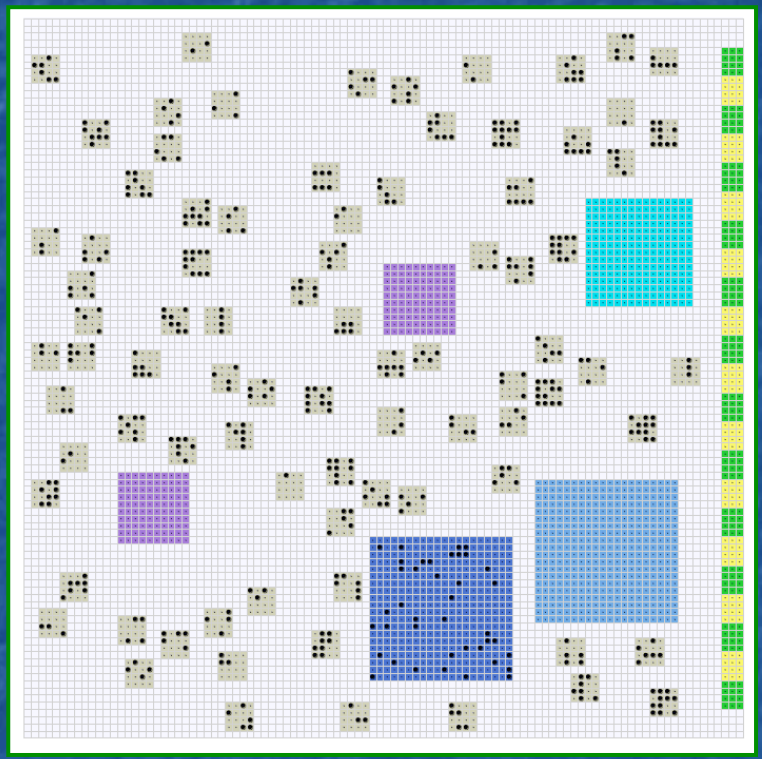
SIR - A Basic Epidemic Model



Can be divided into subgroups if needed for a particular disease (e.g., pertussis, AIDS)

Using agent-based models to understand the spread of infectious diseases in Newfoundland

- Model structure
  - Buildings include 84 houses, 2 churches, a school, an orphanage, a hospital, and 23 boats
  - 503 agents with demographic characteristics (age, sex, occupation, religion, etc.) determined from 1921 census records
  - Divided into households according to census
  - Most men are fishermen assigned to particular boats; older women or young women without children may also go to assigned boats
  - Women with young children stay home
  - Children aged 5-15 go to school
  - Some doctors, nurses, teachers, and assorted other occupations
- Agents are home every night, go to boats, school, etc during the day (M-Sat); everyone has chance of going to church on Sunday



- Each simulation begins with a single case chosen randomly
- Simulations run for 200 time units (100 days)

Present activities

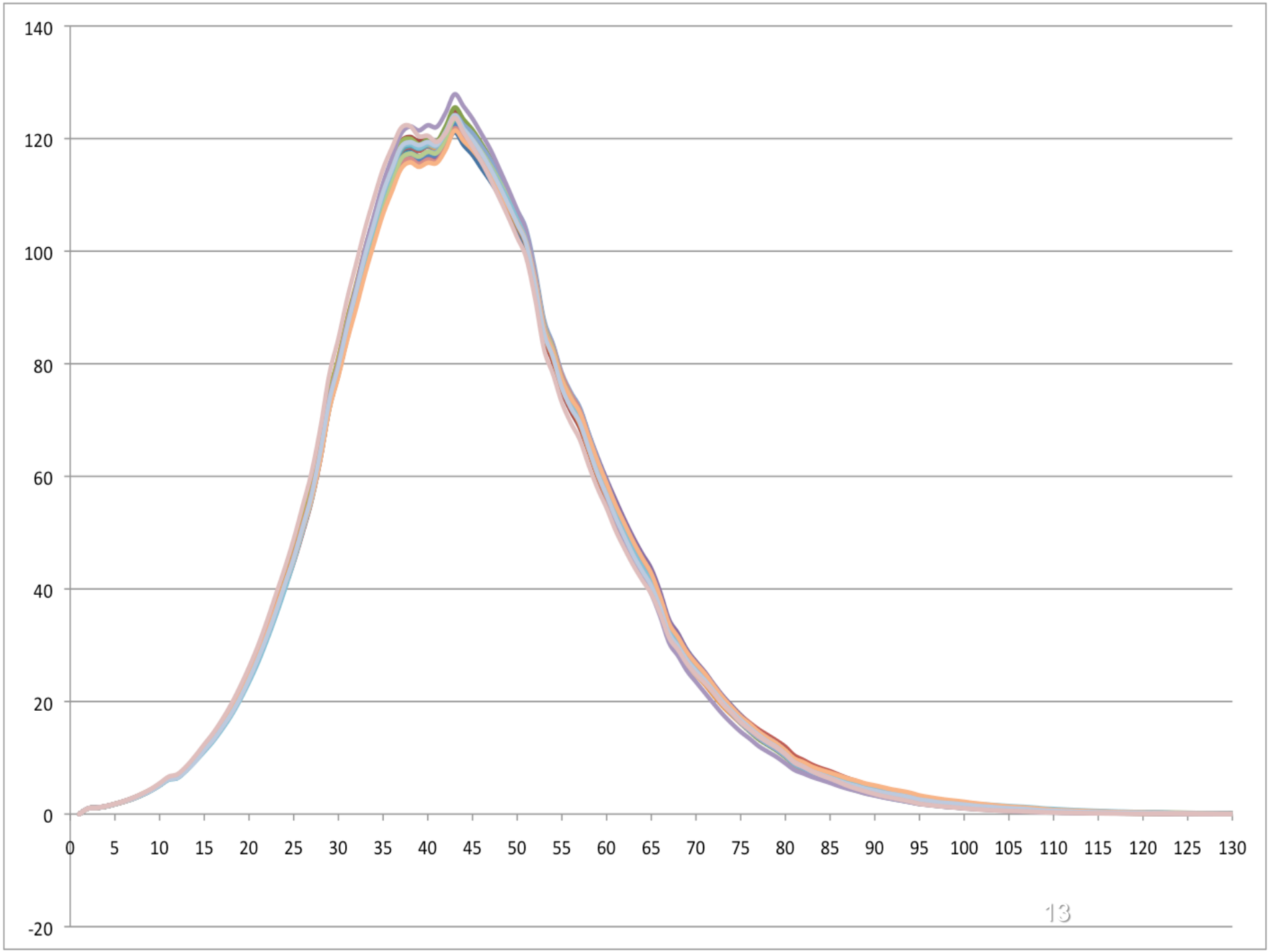
- Sensitivity analyses
  - Single and multiple variable analyses for random mixing model
  - Single variable analyses and one dual variable analysis of partial directed movement model

Other Applications of the Approach

- Model to be used as a base for future research with linked communities, other diseases, and/or other populations
  - Multiple communities within Newfoundland to study geographic spread
  - Other infectious diseases – typhoid, malaria, smallpox, etc.
  - California Mission Period

What I Actually Did

- Replication Study
  - The replication study compares 20 sets of 1000 runs in order to find a normal range of variation between curves when using identical parameters. It is conducted to ensure that the model is running consistently and appropriately according to its design.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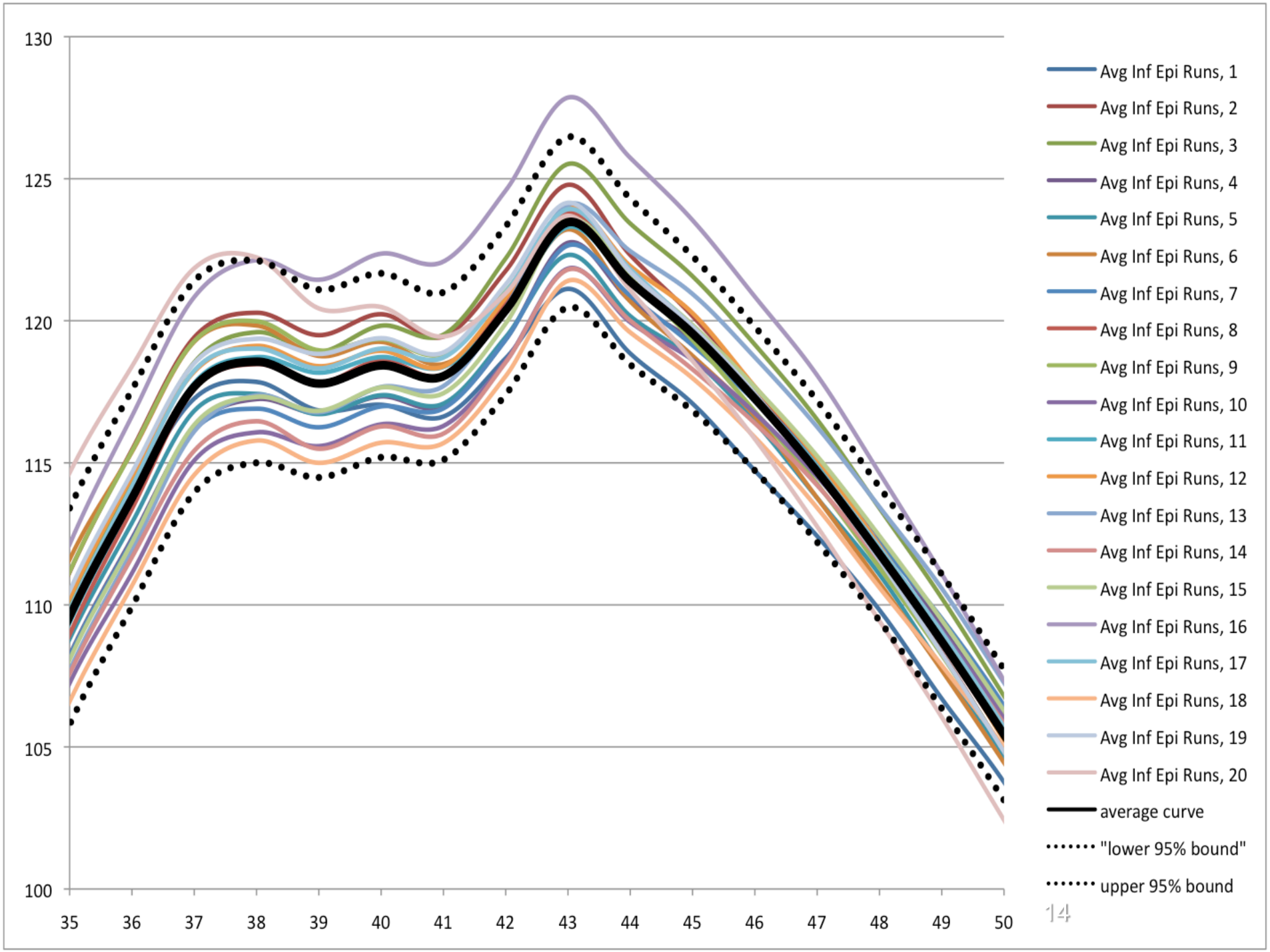
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Avg Inf Epi Runs, 1
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Avg Inf Epi Runs, 3
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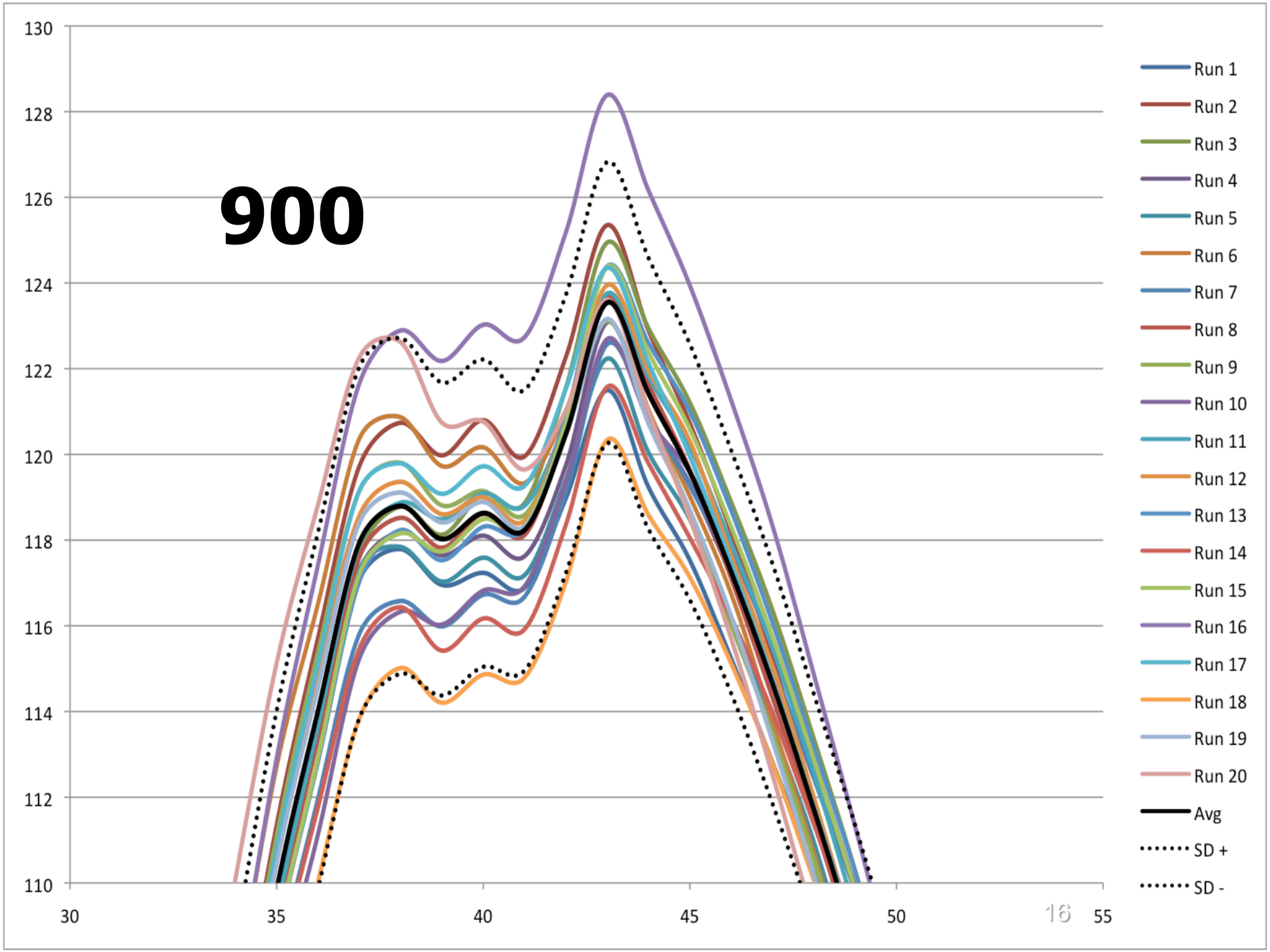
Avg Inf Epi Runs, 16
Avg Inf Epi Runs, 17
Avg Inf Epi Runs, 18
Avg Inf Epi Runs, 19
Avg Inf Epi Runs, 20
average curve
"lower 95% bound"
upper 95% bound

Recent Work

- Repetition Study
  - How many runs are adequate to determine the true form of the model?
  - Started with 1000 runs in the Replication Study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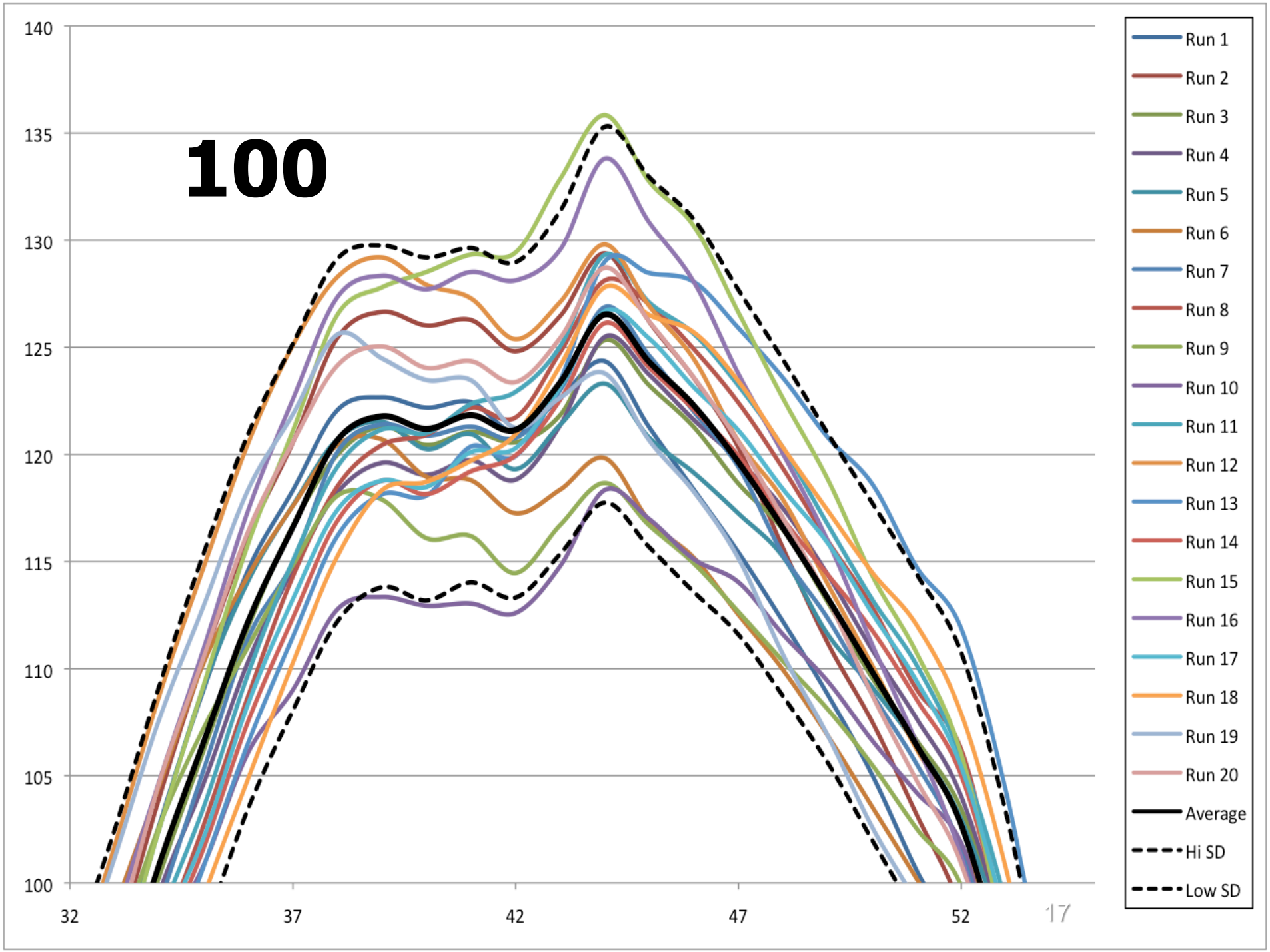
Run 20
Avg
SD +
SD -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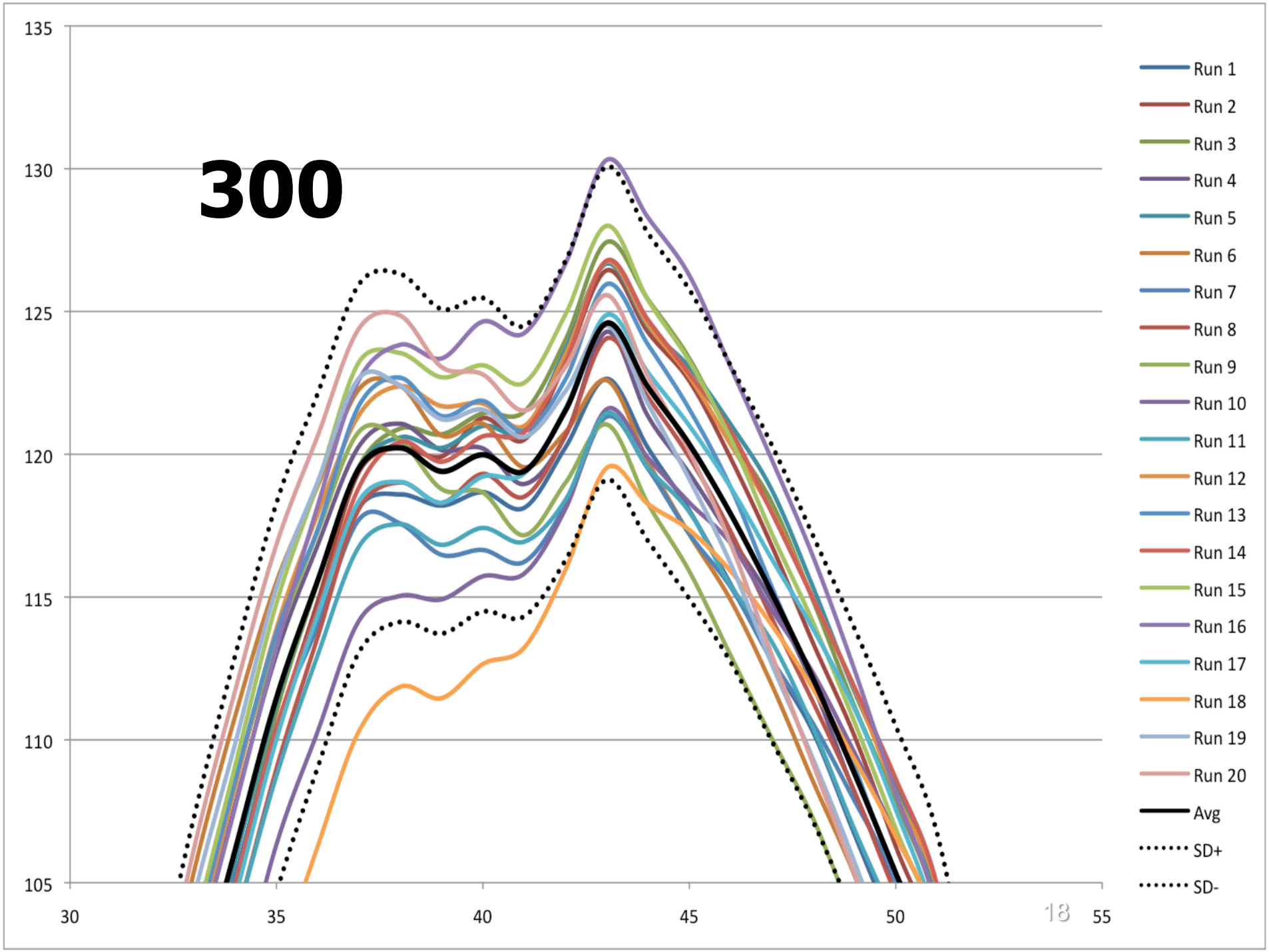
Average
Hi SD
Low SD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Avg
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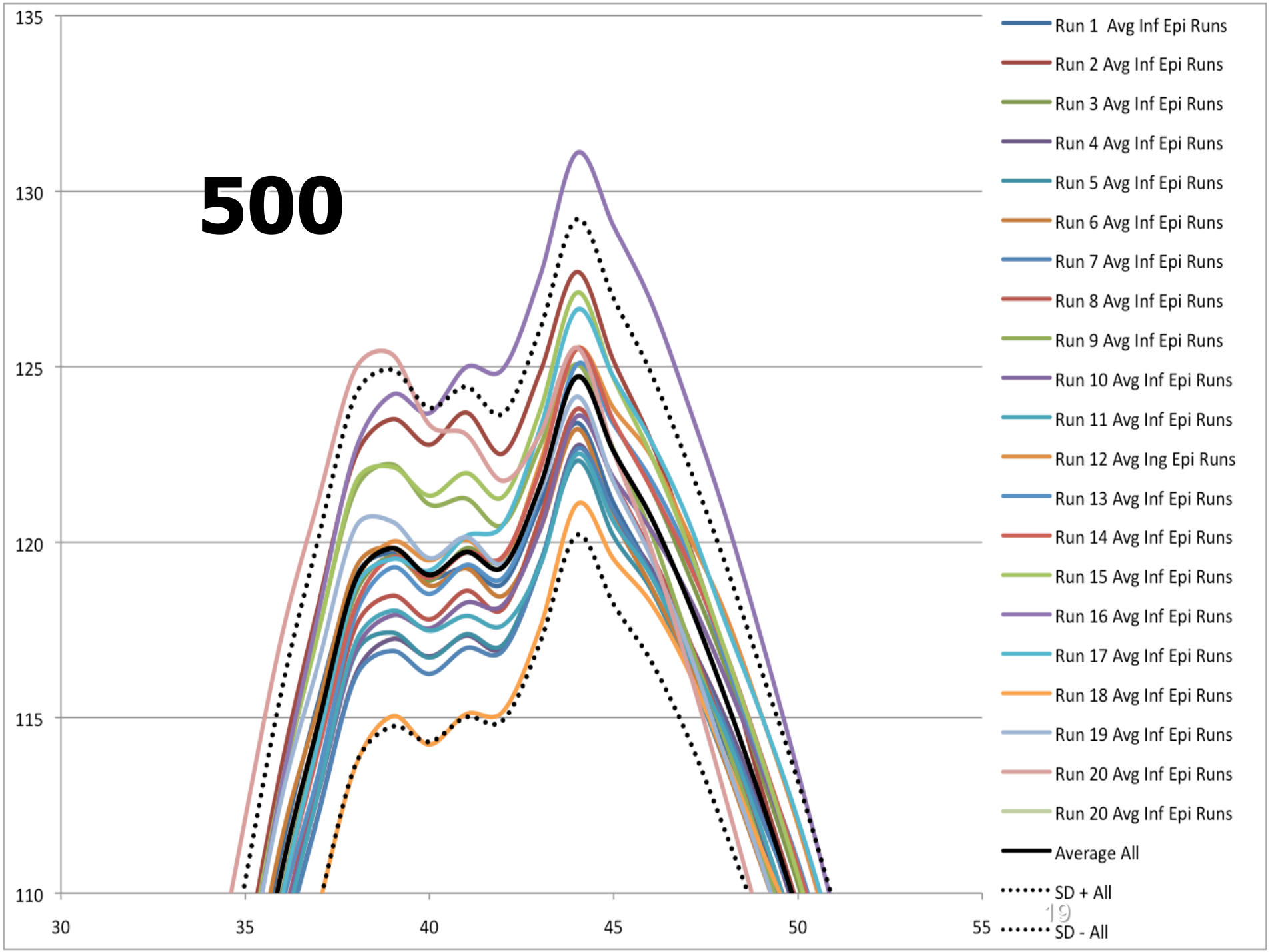
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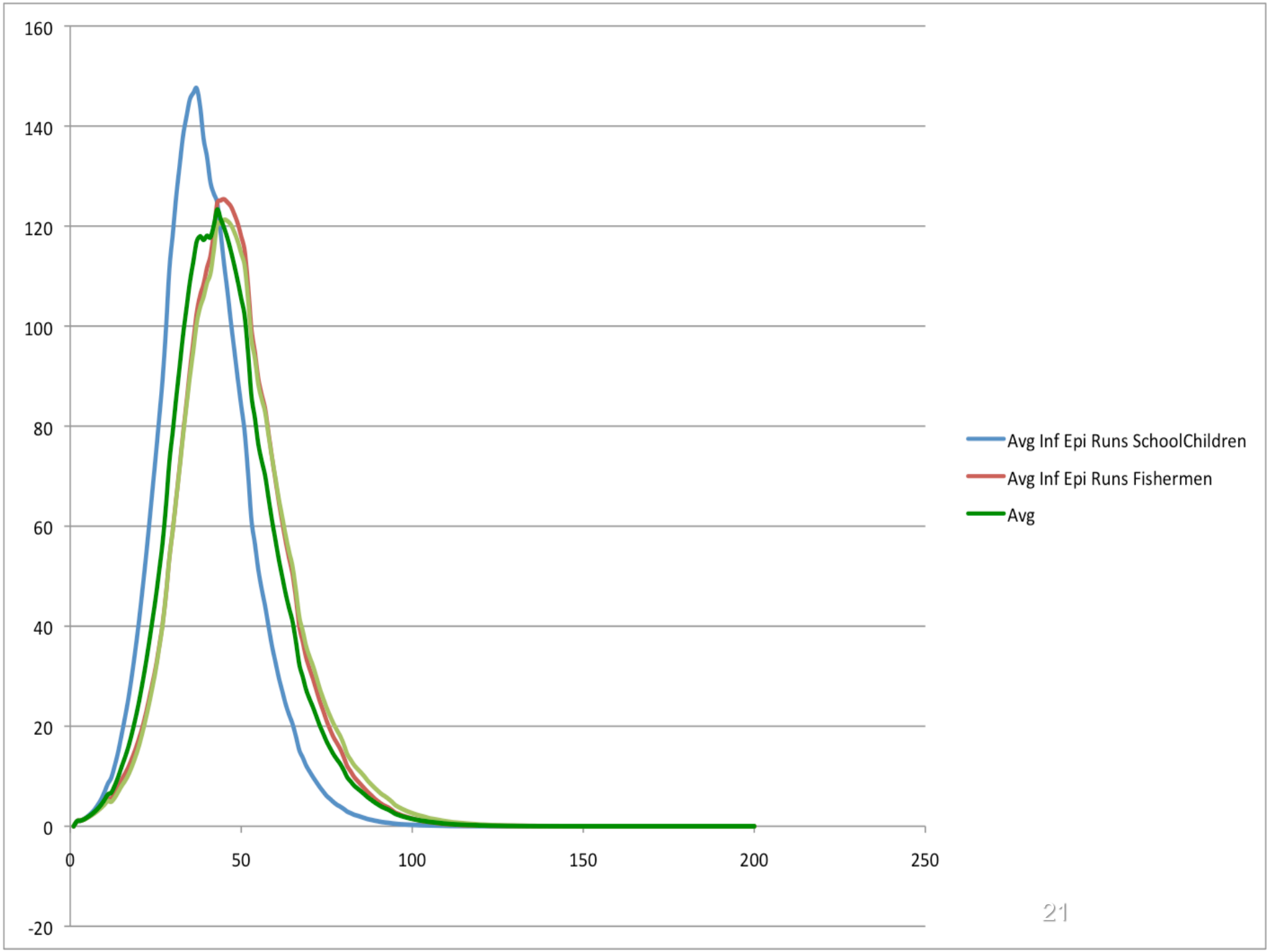
Run 18 Avg Inf Epi Runs
Run 19 Avg Inf Epi Runs
Run 20 Avg Inf Epi Runs
Run 20 Avg Inf Epi Runs
Average All
SD + All
SD - All

What makes the three peaks?

- Fishermen
- School Children
- All Others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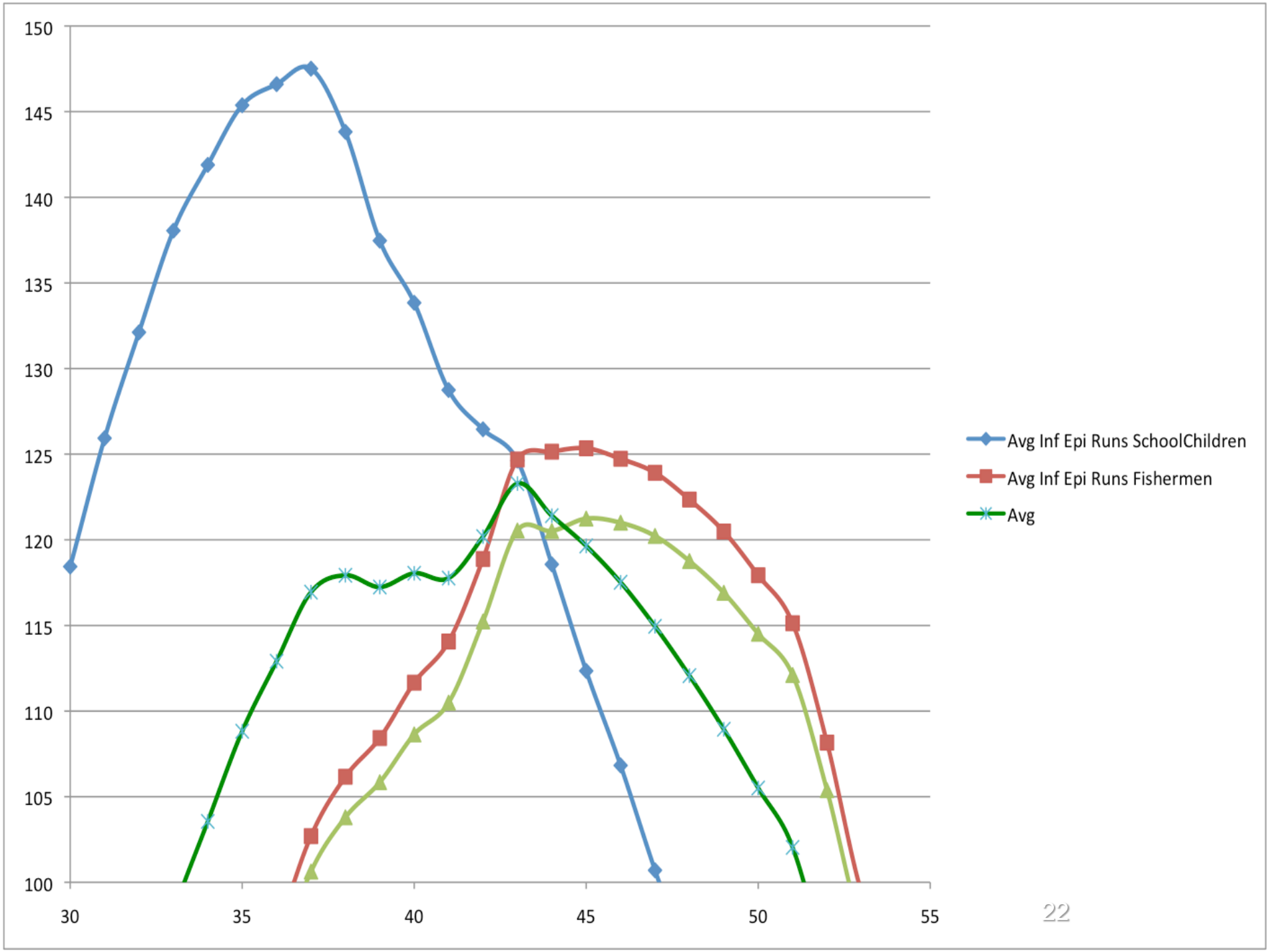
Avg Inf Epi Runs SchoolChildren
Avg Inf Epi Runs Fishermen
Avg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Avg Inf Epi Runs SchoolChildren
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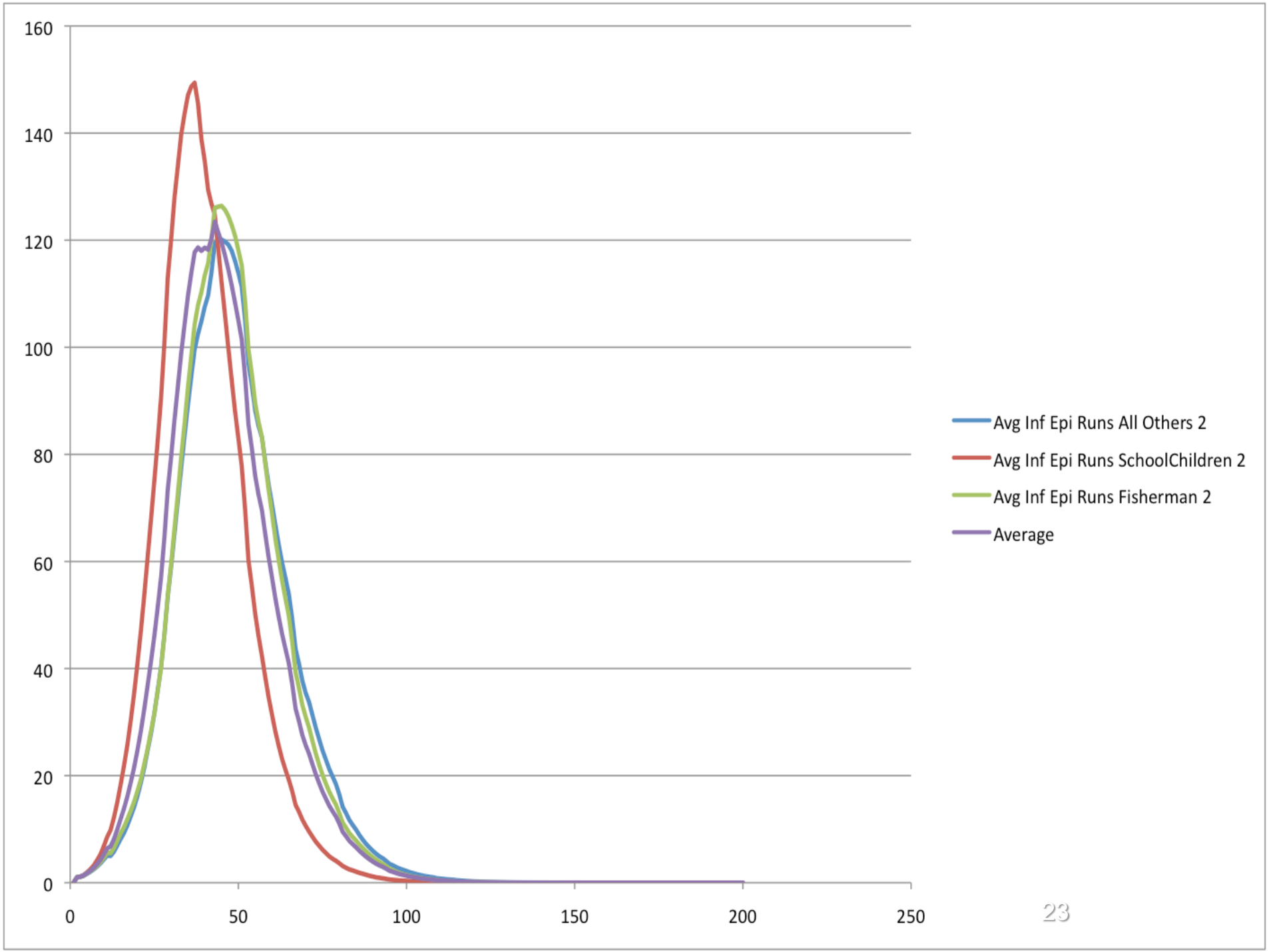
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Avg Inf Epi Runs SchoolChildren 2
Avg Inf Epi Runs Fisherman 2
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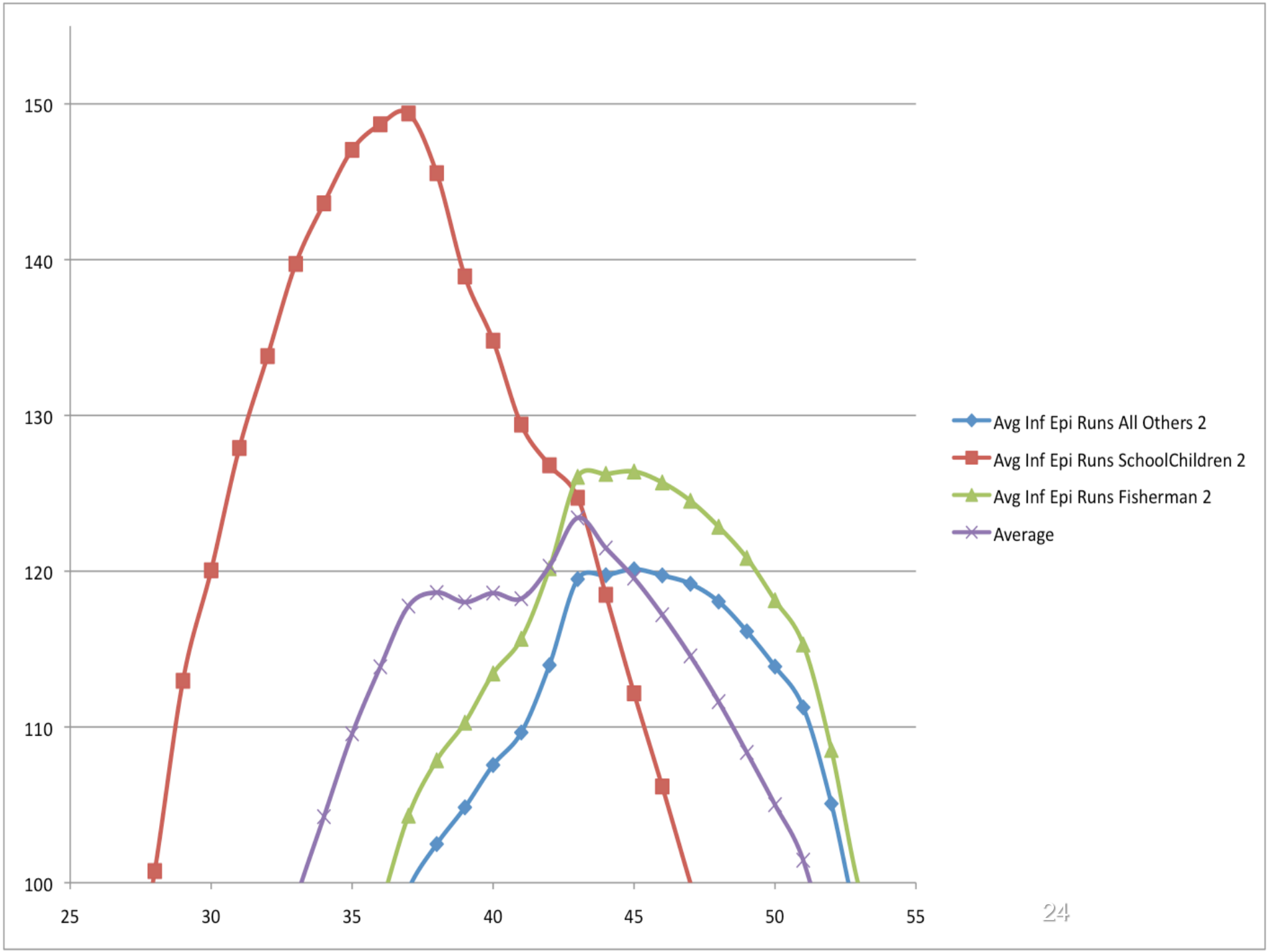
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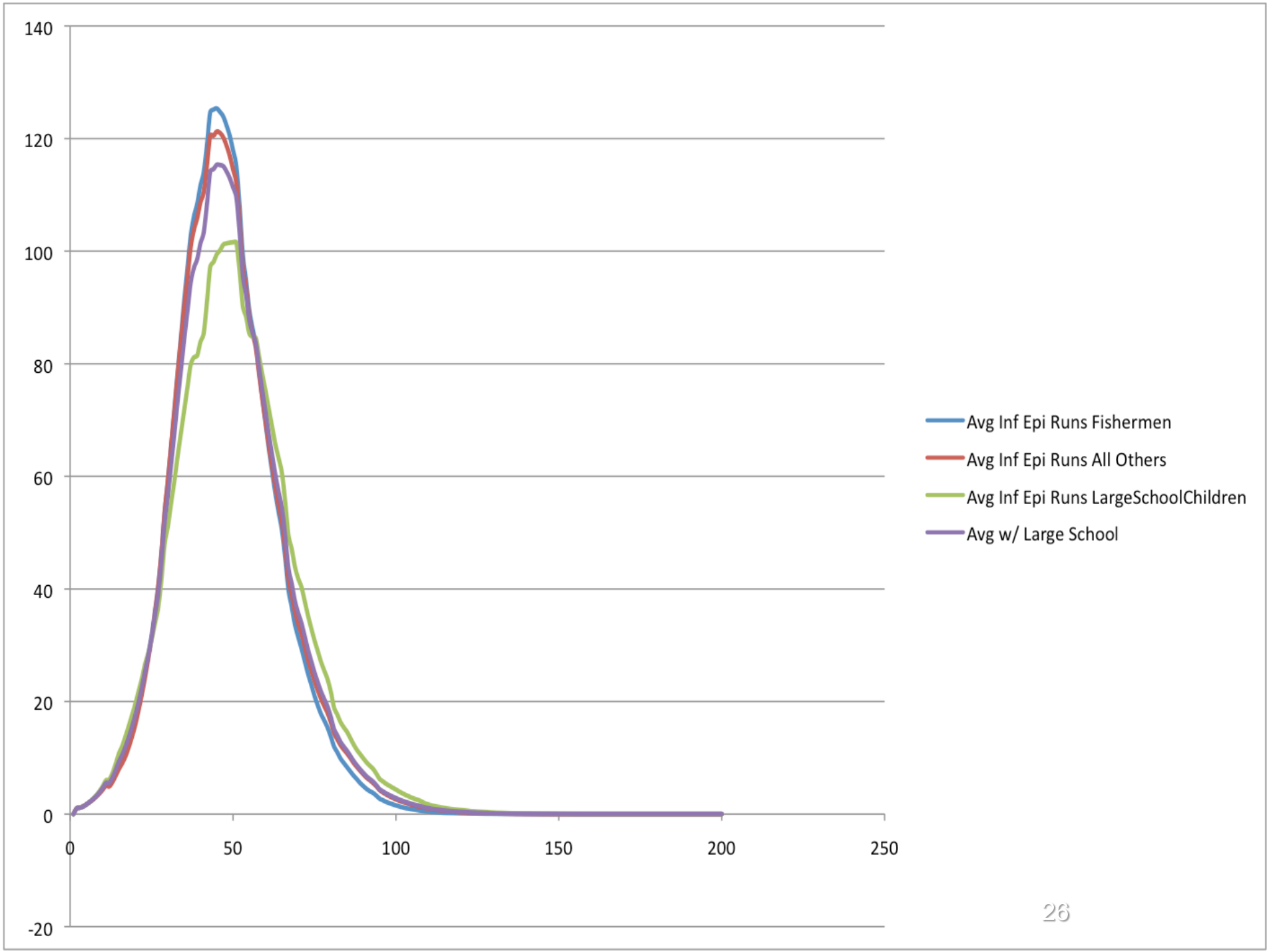
Avg Inf Epi Runs All Others 2
Avg Inf Epi Runs SchoolChildren 2
Avg Inf Epi Runs Fisherman 2
Average

What affects the School Children?

- Two peaks from School Children
  - Family size?
- Size of school
  - Increased size of school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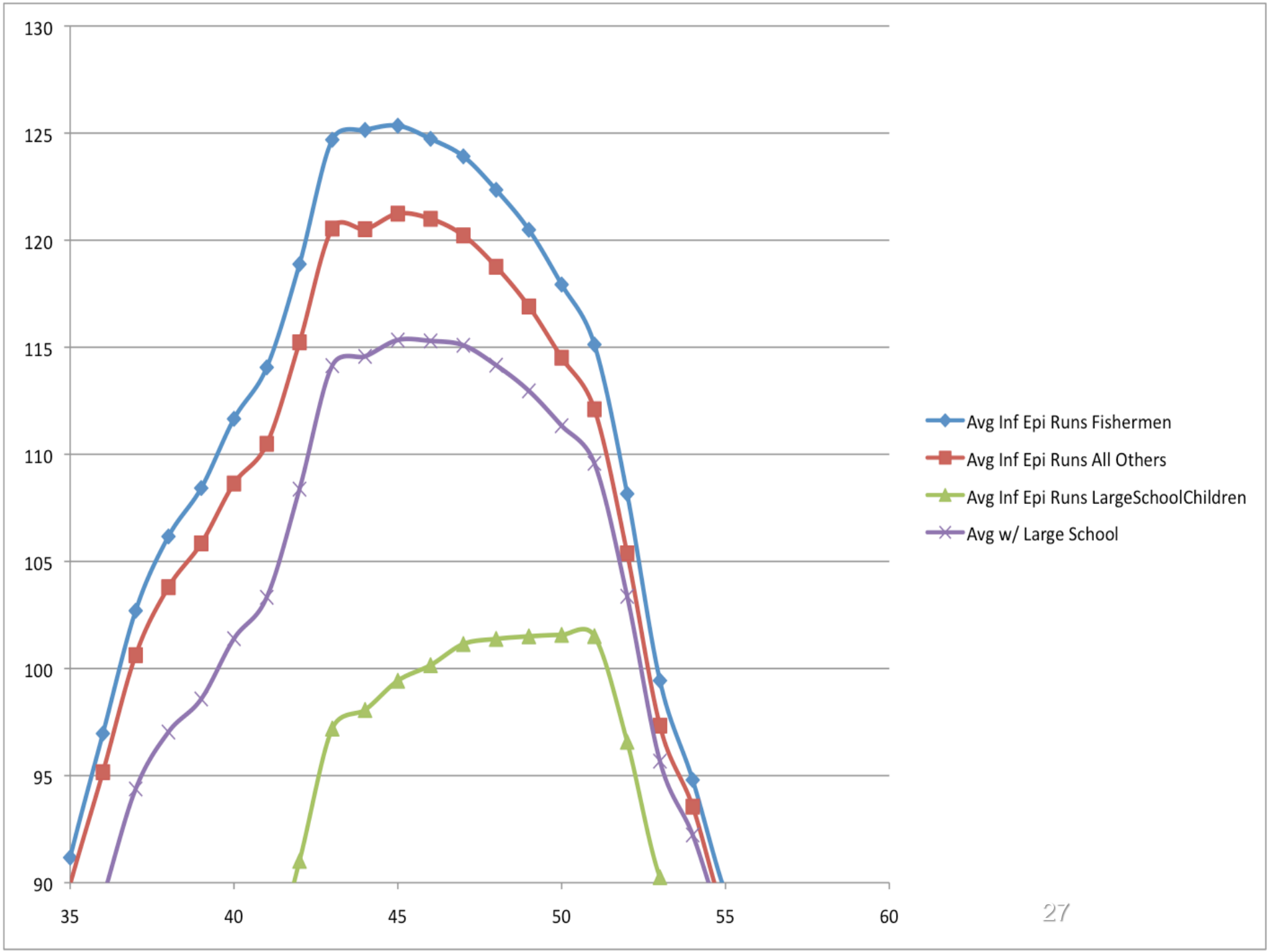
Avg Inf Epi Runs Fishermen
Avg Inf Epi Runs All Others
Avg Inf Epi Runs LargeSchoolChildren
Avg w/ Large School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Avg Inf Epi Runs Fishermen
Avg Inf Epi Runs All Others
Avg Inf Epi Runs LargeSchoolChildren
Avg w/ Large School

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