

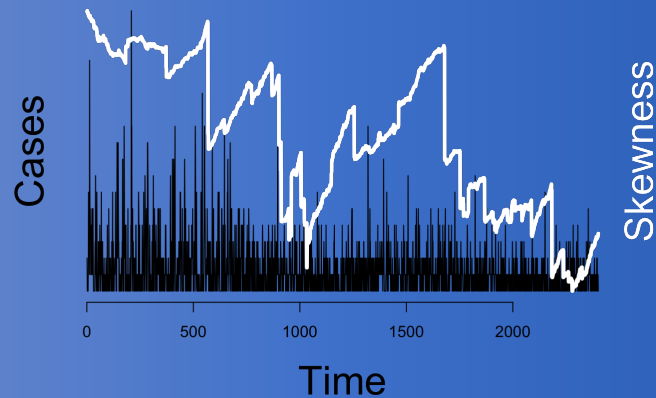
Spatial pattern formation in infectious diseases on the verge of elimination

Paige Miller & John M Drake
Graduate Student Symposium
January 28, 2017

Early warning signals for critical transitions

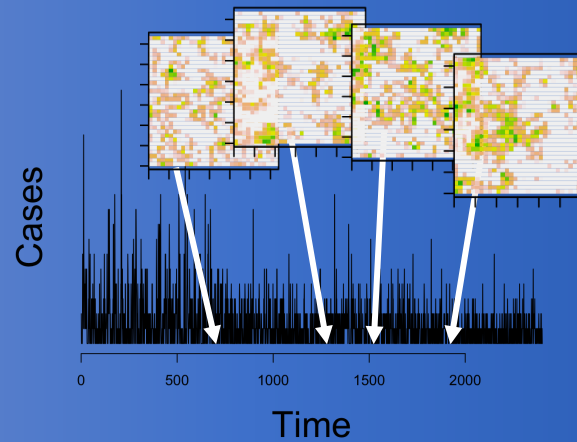
Context:

Tipping points
in ecology &
epidemiology



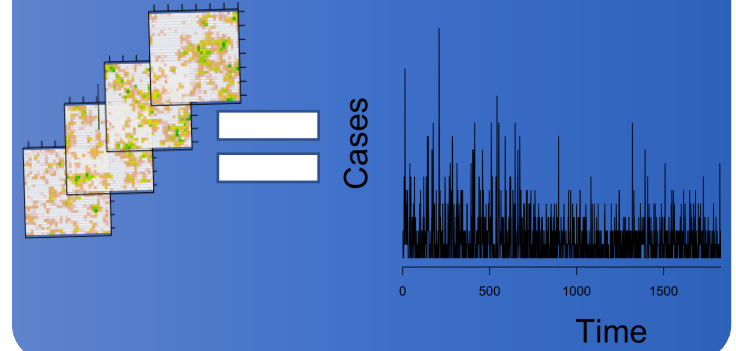
Complication:

Prediction
requires long
time series



Question:

Can spatial
data be
substituted for
time series?



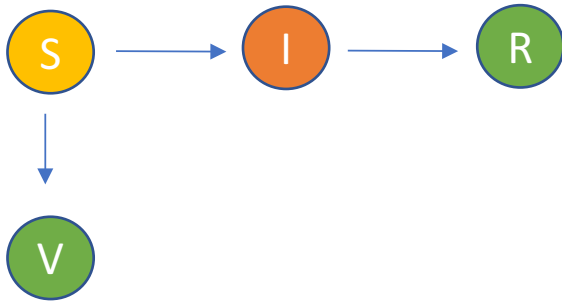
Predictions:

Spatial signals will be more reliable
than temporal signals given equal
amounts of data points.

Spatial signals will require fewer
data points to make equally
accurate predictions.

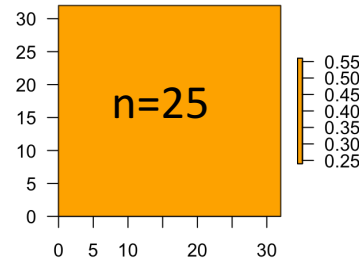
Experimental design

Simulations

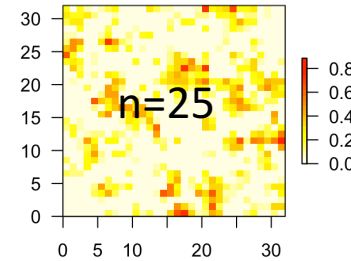


Transmission environments

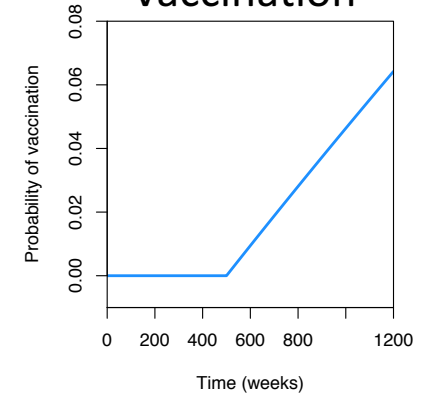
Constant



Patchy

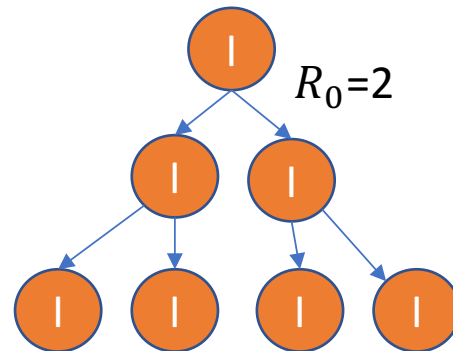


Vaccination



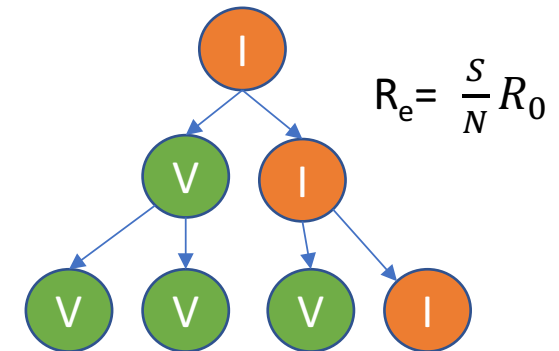
Transition to elimination depends on rate of transmission

R_0



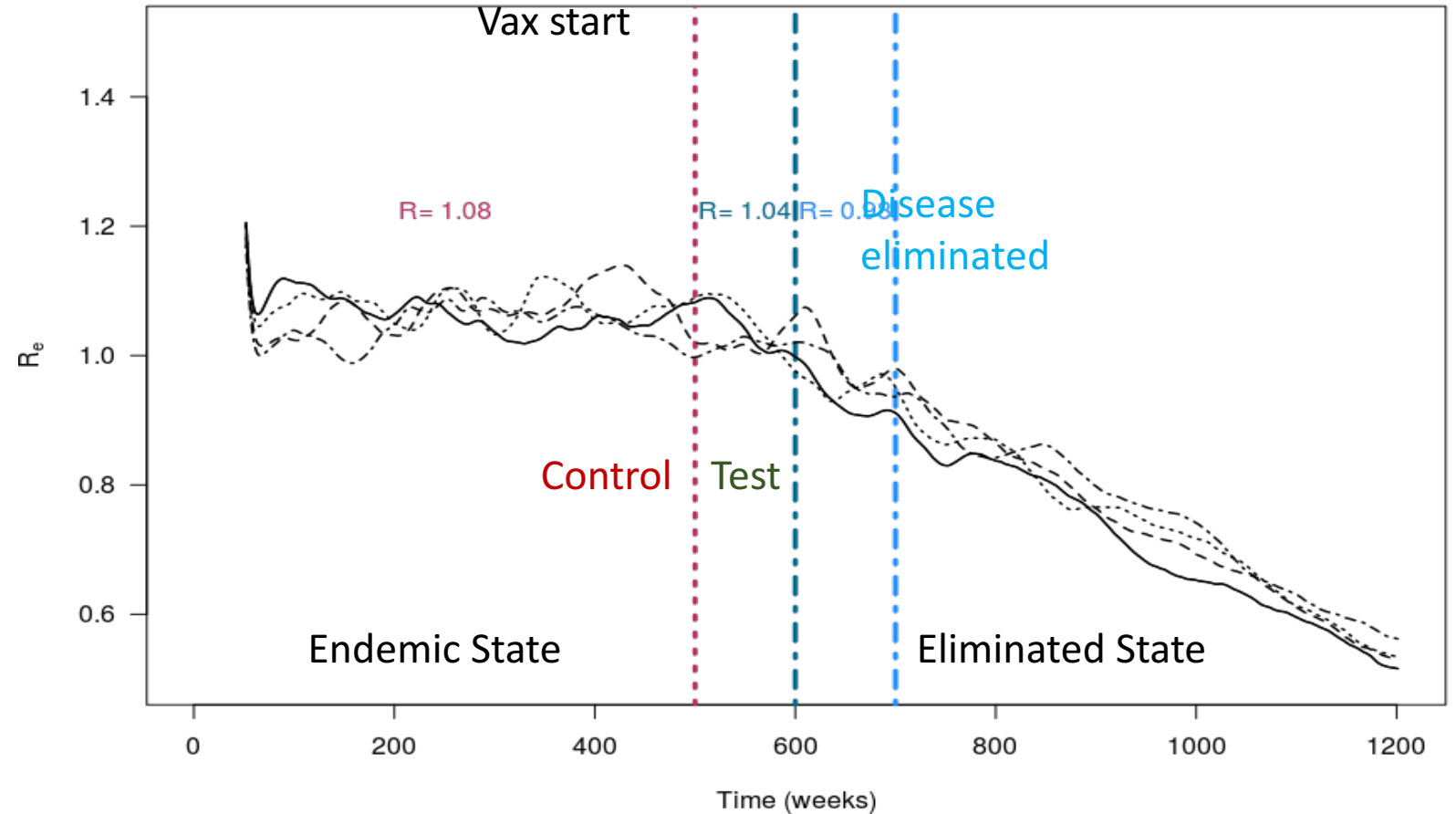
Vaccination

R_e

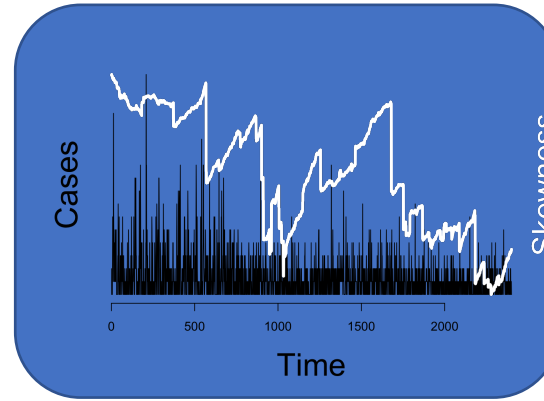


Calculating R_e in spatial SIR model

$$\begin{aligned}
 R_e &= \frac{1}{n^2} \sum_{i=1}^{\infty} \overbrace{\bar{S}}^{\text{Mean (n=dim)}} \underbrace{(1 - e^{-\beta g})}_{P(\text{inf.} | g)} \underbrace{(1 - p)^g p}_{P(g)} \\
 &= \frac{\bar{S} p}{n^2} \sum_{i=1}^{\infty} (1 - b^g)(1 - p) \\
 &= \frac{\bar{S}}{n^2} \frac{(b - 1)(p - 1)}{(1 - p)(pb - b + 1)}
 \end{aligned}$$



Temporal



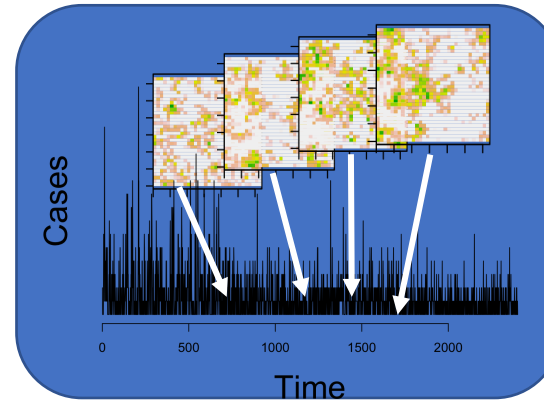
- Patterns in cases over time



200 weeks of data (100 null, 100 test)

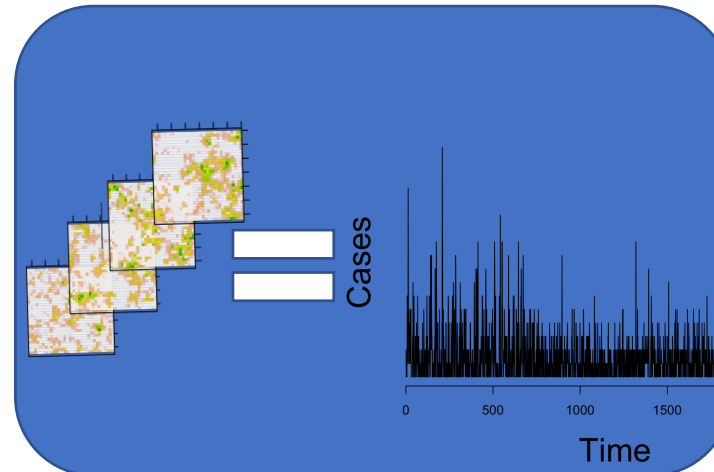


- Patterns in cases in space over time



- Skewness
- Autocorrelation
- Coeff. of Variation

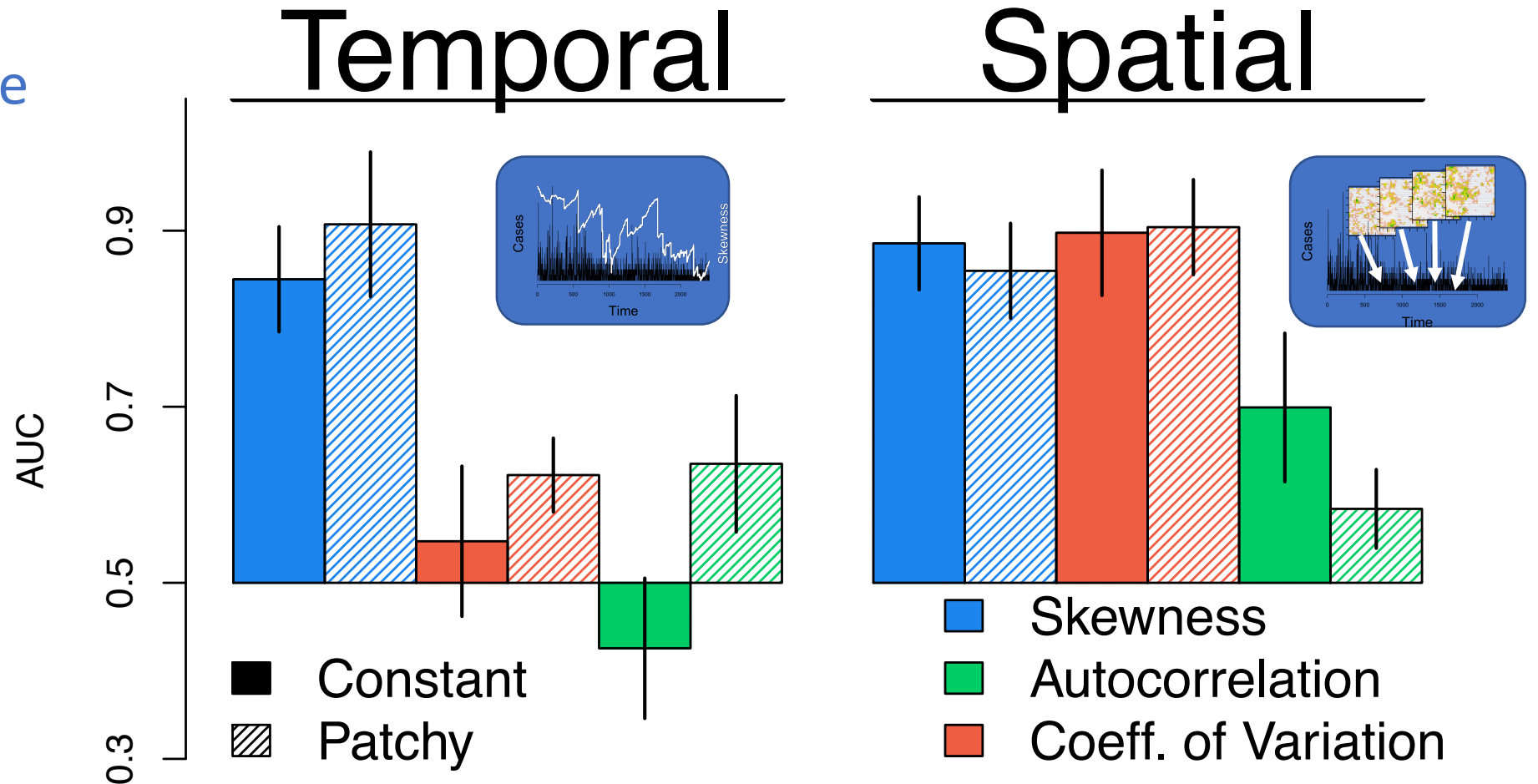
Periodic spatial sampling



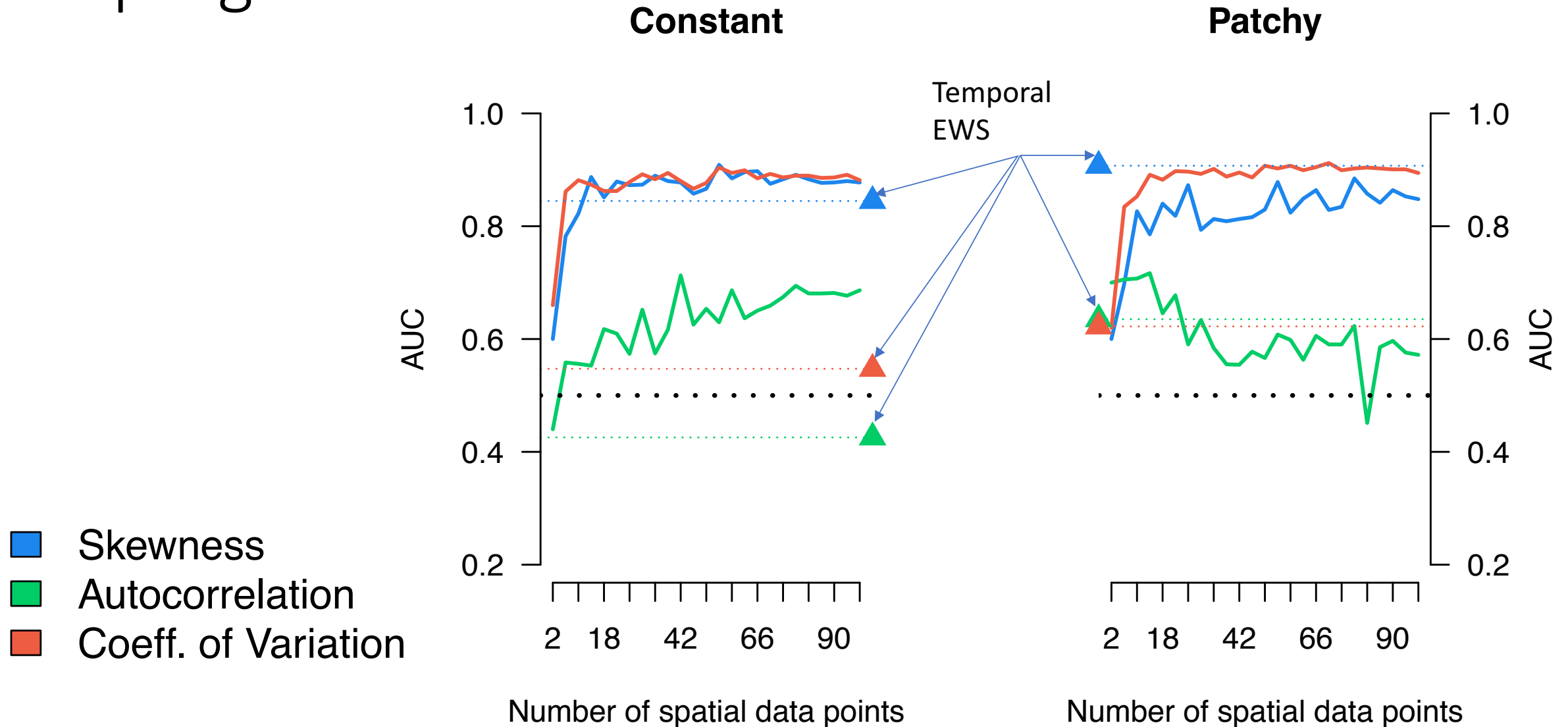
- Patterns in cases in space over fewer time points

Spatial signals are more reliable than temporal signals given the same number of data points

Performance
of leading
indicators



Less spatial data is necessary to document progress towards elimination



Conclusions

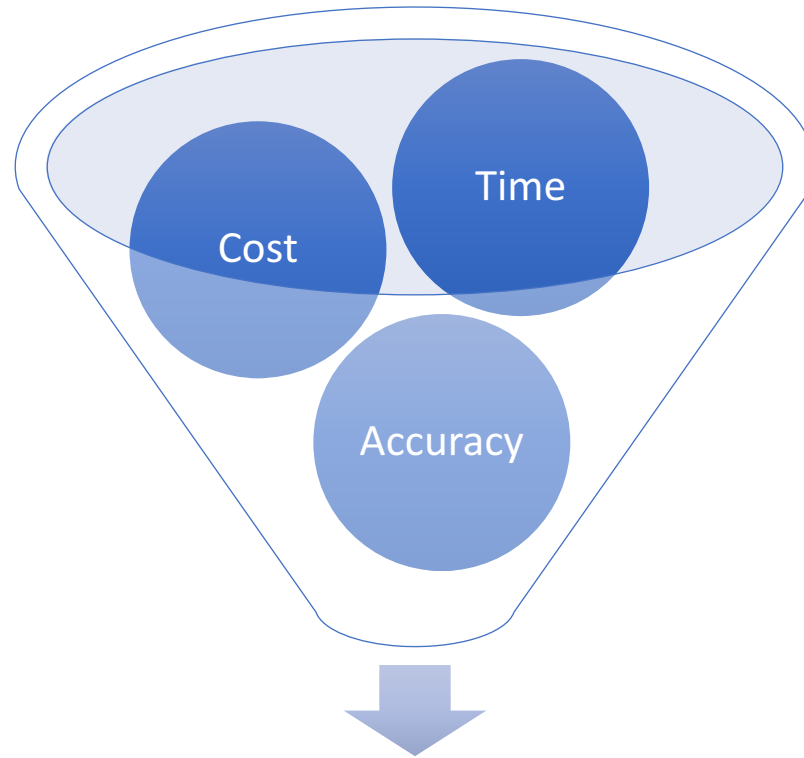
Spatial signals are
more reliable than
temporal signals
given equal amounts
of data points.

True

Spatial signals require
fewer data points to
make equally
accurate predictions.

True

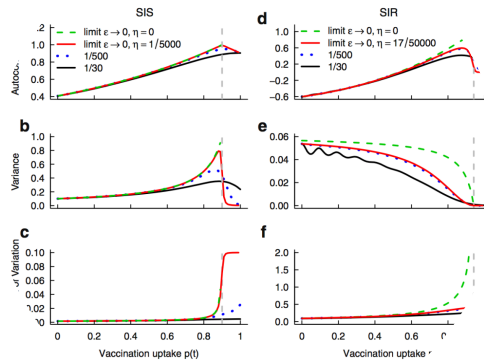
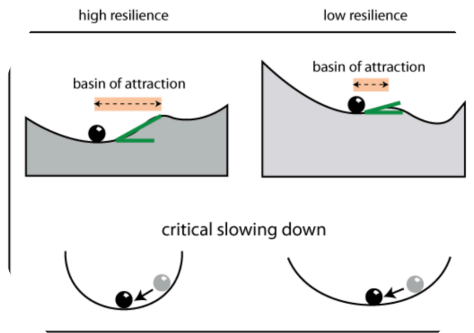
Why does this matter?



Designing better long term surveillance projects

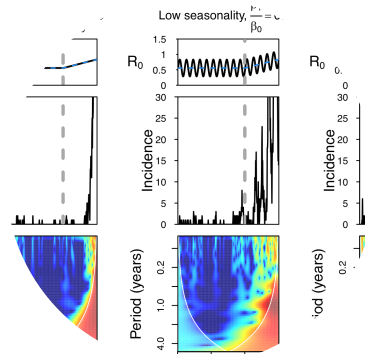
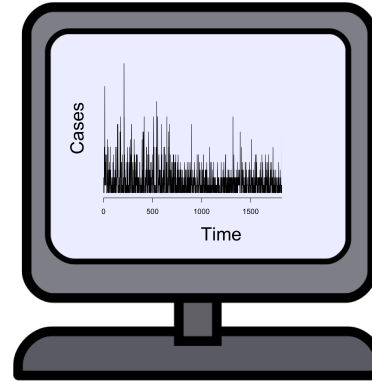
Early warning signals for epidemic transitions

Theory

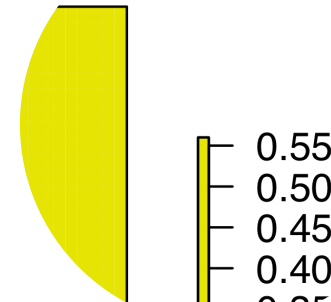


Analytical solutions
O'Regan & Drake (2013)

Numerical Validation

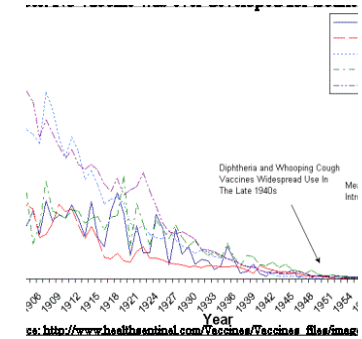


Seasonal
Miller et al. (in prep.)



Spatial

Empirical evidence



Next
steps

Acknowledgements

People

- Eamon O'Dea
- Drew Kramer
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- Deeran Patel
- Tom Pulliam
- Drake Lab

Funding



Resources



Questions?