Recommendations for Infectious Disease Modeling

Summary of Scientific Findings - H1N1pandemic

May 4, 2010

RECOMMENDATIONS

There is general agreement that the 2010 H1N1 pandemic was a test of U.S. systems for protecting the public from a serious influenza outbreak. We all learned a great deal about how existing systems do and do not work. MIDAS investigators are particularly thankful to many groups and agencies that provided data and information throughout the outbreak. We recognize that health agencies were overstretched and greatly appreciate their time and willingness to share. There was also significant sharing of information among the worldwide community of modelers about estimating parameters, now-casting, prediction, effects of behaviors and interventions, and implications of policy decisions.

There remain systemic problems to be identified and addressed. Data acquisition, data sharing, the role of modeling, tension among various goals (e.g., transparency and efficiency), and communication of information are significant challenges for the modeling community. Below are MIDAS's recommendations to improve the usefulness and timeliness of modeling to support decision making:

Initiate broad discussion on the purpose and organization of infectious disease modeling in the United States.

Improve transparency of decision-making process. It was rarely clear to MIDAS modelers (1) who wanted modeling results, (2) how results were reported, (3) to whom results were reported, or (4) the impact of modeling on policy decisions. It is not clear whether modeling results should be or are reported to CDC, NIH, DHHS, or other levels of decision-making.

Improve communications among modelers and DHHS. It is important to build relationships and develop protocols in advance of an emergency. Modelers need to understand the context in which questions are asked as well as how various policy decisions were prioritized.
  - ✓ Establish an exchange and/or training program to cross train modelers and DHHS staff
  - ✓ Involve modelers in discussions on developing modeling questions and scenarios
  - ✓ Involve modelers in discussions of interpretation and implications of modeling research

Improve data and knowledge sharing among DHHS agencies. There may need to be special rules for expedited sharing in a disaster. Modelers are asked "Where are we now and what do we expect to happen?" Now-casting and anticipation of future dynamics in the absence of good current data are too speculative.
  - ✓ Develop systems to collect data necessary for planning (e.g., serological surveys, number of people infected or hospitalized)
  - ✓ Develop systems for analyzing, formatting, and sharing data for a variety of purposes, including modeling
  - ✓ Develop systems for "reality tests" of model results

Improve the communication of modeling results to non-expert audiences
  - ✓ Develop, test, and implement better visualization tools
  - ✓ Improve the presentation of model results to a variety of audiences

SCIENTIFIC FINDINGS

NOTE: MIDAS is made up of independent, but collaborative, research groups. While there is broad consensus on many points, not all research groups agree on all the findings reported here.

H1N1 DYNAMICS AND PARAMETERS

Generation time and incubation period for H1N1 were comparable with seasonal flu. As of November, 2009, the US epidemic was growing slowly with R estimated to be ~1.2. The general picture was of low ILI attack rate, low health impact (small percentage of population seeking care), with most transmission in children.	Fred Hutchison Cancer Research Institute / University of Washington
Determined the reproduction number of H1N1 by analyzing the dynamics of the complete case series in Mexico City. The initial reproduction number (95% CI) was 1.51 (1.32–1.71) based on suspected cases and 1.43 (1.29–1.57) based on confirmed cases before 20 April. The longer time series (through 25 April) yielded a higher estimate of 2.04 (1.84–2.25), which reduced to 1.44 (1.38–1.51) after correction for ascertainment bias. [22]	Yale University/ University of Texas
Using the US line list, MIDAS estimated that the basic reproduction number for H1N1 in the early part of the US epidemic was on the order of 1.7 to 1.8. This was slightly higher than most other estimates, reflecting perhaps the use of a different data set, different adjustments for changing ascertainment (which was a focus of our analysis), local variability in transmissibility, or other factors. [27]	Harvard School of Public Health

Using data from a summer youth camp outbreak, estimated an attack rate of 51% among 96 youth camp participants. A cabin secondary attack rate (SAR) of 41.6% (21.0%- 65.7%) and a camp local reproductive number of 2.7 (1.7- 4.1) were observed among ≤ 17 year-olds (children). Among the 136 contacts in the 41 households with an index case who attended the camp, the SAR was 10.9% (5.3%- 21.0%) and 3.7% (1.6%- 8.3%) for children and adults (≥ 18 years). The strong age effect combined with the low number of susceptible children per household (1.2) plausibly explains the lower than expected household SAR, illustrating the importance of other venues where children congregate for sustaining community transmission. [submitted for publication]	Fred Hutchison Cancer Research Institute / University of Washington
Using travel data, estimated that case numbers in Mexico were 2 or more orders of magnitude too low, suggesting that severity there was severely overestimated. [20]	Harvard School of Public Health
Assisted CDC in developing multiplier models to estimate symptomatic cases and deaths from hospitalizations. [24]	Harvard School of Public Health
Determined that a key parameter for modeling influenza is the symptomatic rate (the percentage of people who are infected and show symptoms), which is difficult to obtain from current available data, but can greatly impact overall results. [not published]	University of Pittsburgh
School-age children typically experience the highest attack rates in primarily naive populations, with the burden shifting to adults during the subsequent season. The group demonstrated that new pandemic strains of influenza are expected to shift the epidemiological landscape in exactly this way. The analysis provides a simple demographic explanation for the age bias observed for H1N1/09 attack rates, and a prediction that this bias will shift in coming months. [in press]	Yale University/ University of Texas
Based on an outbreak in a New York City public school, MIDAS estimated key natural history parameters of the H1N1 virus were estimated including the incubation period, the generation time (also called the serial interval), and the duration of illness. H1N1 was found to have a very similar natural history to previously circulating influenzas. We also characterized the transmissibility of H1N1 by estimating the within school reproductive number, household secondary attack rates, and household transmission probabilities. [18]	University of Pittsburgh

Working with North and South America data and the Pan American Health Organization, MIDAS characterized the dynamics of H1N1 during the late spring and early summer in North and South America, estimating the reproductive number of the virus in 19 countries using PAHO surveillance data. A significant association was found between the estimated reproductive numbers and latitude, with more southern locations having higher estimates of the reproductive number, suggesting a strong seasonal component to H1N1 transmission. [in preparation]	University of Pittsburgh
Estimated that the case-fatality ratio was between approximately 1/2000 and 1/14,000 symptomatic cases, and provided corresponding estimates of the case-hospitalization and case-ICU ratios. [23]	Harvard School of Public Health
Using the number of deaths up to a given point in time to estimate the Case Fatality Ratio during an emerging epidemic, one can underestimate by a factor of up to 5 (using parameters similar to 1918). Estimating epidemic's death toll, incidence, and case fatality ratios before serological data is available is a tricky issue.	Harvard School of Public Health
MIDAS investigated variability in simulated outcomes due which are due to uncertainty in the social network structure, rather than the disease characteristics or initial conditions. Substantial variability between cities (Miami and Seattle) can be attributed to differences in age and household size distributions. A similar county level analysis for Washington state showed that variability can be attributed to differences in the fraction of school age children, household sizes, and urban/rural contact patterns. Variability across different instances of networks generated by stochastic network models was negligible compared to the variability across different instances of an epidemic on any single network.	VBI
MIDAS evaluated possibilities of a "third wave" of H1N1 pandemic. Potential mechanisms evaluated include: (1) wintertime increase of seasonal forcing of transmission with increasing Ro; (2) changes in social contact patterns; (3) progressive viral adaptation with increased human to human transmissibility, and (4) emergence of new immune escape variant. The results showed that increased transmission during a mild epidemic increases attack rate and may lengthen tail; loss of immunity combined with an increase in transmissibility can produce additional peak; vaccination reduces peak and overall attack rate in third wave even with substantial increase in transmissibility and loss of immunity. [not published]	University of Pittsburgh
In the period when severity was unclear and unusual measures were under consideration to reduce morbidity and mortality, we defined conditions under which passive immunotherapy could be a successful population-wide strategy. [29]	Harvard School of Public Health

ANTIVIRAL USE AND DISTRIBUTION

Just prior to the pandemic, MIDAS [28] outlined a strategy to minimize the risk of antiviral resistance spreading using sequential or simultaneous multiple drug treatment at the population level and collaborated with Australian colleagues [21] to translate this into policy recommendations.

Harvard School of Public Health

Later in the epidemic, MIDAS recommended that predispensing of antivirals to individuals at high risk of complications would under very broad assumptions likely reduce total mortality in the pandemic. [11]

Harvard School of Public Health

Although a simple pro rata distribution schedule is competitive with optimized strategies across a wide range of uptake and wastage, other equally simple policies performed poorly. More aggressive use of the Strategic National Stockpile could have appreciably slowed the transmission of H1N1 during summer and fall 2009, and thus may be an effective mitigation strategy during the early stages of future flu pandemics.

Yale University/ University of Texas

MIDAS developed simple criteria which ensure that pre-dispensing to certain groups is beneficial for reducing the number of severe outcomes in the whole populations under any scenario on supply and demand of antivirals during an epidemic.

Harvard School of Public Health

VACCINE USE AND DISTRIBUTION

There is general agreement that pandemic H1N1 vaccine arrived too late to mitigate the epidemic in United States. Had vaccine arrived in September 2009, as originally planned, MIDAS found that over 2,000 deaths and 60,000 hospitalizations could have been avoided. Mass vaccination, along with immunity from the first two waves, may have prevented a third wave of pandemic influenza in the winter and spring of 2010. [submitted for publication]

Fred Hutchison Cancer Research Institute / University of Washington

Under a wide variety of scenarios, an effective vaccination program must start 4-8 weeks prior to the peak of the pandemic, and is greatly influenced by the rate at which vaccine can be introduced into the population. [not published]

University of Pittsburgh

When vaccine is distributed during later stages of an epidemic (as it was in case of the 2009 H1N1 pandemic) after sizeable depletion of susceptibles among children has already occurred, vaccination to prevent severe outcomes, particularly among individuals with underlying health conditions, becomes key. We recommended the inclusion of high-risk adults among top priority groups for vaccines. [8]

Harvard School of Public Health

Optimal vaccine allocation is achieved by prioritizing schoolchildren and adults aged 30 to 39 years. Schoolchildren are most responsible for transmission, and their parents serve as bridges to the rest of the population. Results indicate that consideration of age-specific transmission dynamics is paramount to the optimal allocation of influenza vaccines. [MIDAS not cited]	Yale University/ University of Texas

Schools and School Closure

The beginning of elevated ILI in the fall of 2009 occurred an average of 14 days after schools opened in a state. The timing of school opening and elevated ILI was highly correlated. This result provides evidence that transmission in schools catalyzes transmission in the entire community. [submitted for publication]	Fred Hutchison Cancer Research Institute / University of Washington
MIDAS investigated the direct economic and health care impacts for school closure durations of 2, 4, 6, and 12 weeks under a range of assumptions. Closing all schools in the U.S. for four weeks could cost between $10 and $47 billion dollars (0.1-0.3% of GDP) and lead to a reduction of 6% to 19% in key health care personnel. [17]	University of Pittsburgh/ Brookings Institution
School closure in Hong Kong had a large effect in reducing H1N1 transmission. [4]	Harvard School of Public Health

INTERVENTION TARGETING

Maximal reductions in transmission can be achieved by targeting interventions during an epidemic to groups with the highest incidence rate or highest product of incidence rate and force of infection, depending on the type of intervention. [26] A related, analytically optimal approach for vaccine allocation was developed if the vaccine is administered before the epidemic and if the transmission matrix is known. [9]	Harvard School of Public Health
A vaccination strategy targeting groups whose demographics are correlated with frequency of infection in simulated epidemics can decrease the epidemic peak by 70%, and delay it by 46 days compared to the CDC strategy of targeting age groups, which decrease the epidemic peak by 52%, and delay the peak by 25 days.	VBI

SEASONALITY

Absolute humidity, previously implicated by laboratory studies as a cause of flu seasonality, could explain the epidemiologic patterns of seasonality in flu for the last several decades in the United States. [25] Using this work and some real-time estimates of transmission in the United States following the October pandemic peak, MIDAS estimated, in response to a BARDA query, that the winter uptick in transmissibility would be unlikely to result in a "second wave" of transmission.	Harvard School of Public Health

POLICY ANALYSIS

In the first weeks of the pandemic, MIDAS defined the likely mismatch in timing between clear evidence of severity/transmissibility and the need to make decisions concerning pandemic response. [8]	Harvard School of Public Health
MIDAS described a system of surveillance that could implement the WHO summer recommendations to cease counting cases, suggesting a combination of syndromic surveillance and targeted, random viral testing to define the incidence of symptomatic, medically attended infection. [19]	Harvard School of Public Health
Yearly mass influenza vaccination of school children needs to begin before school opens. [this work was submitted for publication]	Fred Hutchison Cancer Research Institute / University of Washington
After examining a variety of data sources, MIDAS has advocated wider antiviral prescription guidelines for symptomatic individuals in the US.	Harvard School of Public Health and Fred Hutchison Cancer Research Institute / University of Washington

ROLES OF MIDAS INVESTIGATORS

The Harvard School of Public Health Center for Communicable Disease Dynamics took an active part in analysis and response to the 2009 H1N1 influenza pandemic. The PI, Marc Lipsitch, served on the President's Council of Advisors on Science and Technology (PCAST) Working Group on 2009 H1N1 Influenza and on CDC's Team B. Members of the CCDD both at Harvard and in Hong Kong provided advice to local, state and national government agencies throughout the pandemic.

The University of Pittsburgh evaluated scenarios as requested by the President's Council of Advisors on Science & Technology (PCAST) to assist in forecasting health care demand, and in preparation of guidance documents for local and regional planners.

Members of the University of Pittsburg h team were embedded at BARDA to facilitate communication and refinement of modeling activities. A member of the VBI team was embedded at BARDA to facilitate communication of modeling activities and to demonstrate use of tools.

Members of the Fred Hutchison Cancer Research Institute / University of Washington team led WHO working groups on surveillance and vaccination.

The University of Pittsburgh advised the Department of Homeland Security (DHS), providing parameter estimates for National Infrastructure Simulation and Analysis Center (NISAC) modeling, and performing parallel U.S. model simulation runs to compare with NISAC model runs.

VBI advised the Defense Threat Reduction Agency (DTRA) and Northern Command (NorthCom), providing modeling advice and rapid turn-around development for daily briefings at DHHS based on simulations of New York City, Dallas, and Los Angeles.

Collaborators:

Centers for Disease Control and Prevention
Los Angeles County Health Department
King County WA Health Department
Allegheny County Health Department
New York City Department of Public Health
World Health Organization
Pan American Health Organization
Mexico
Canada
Hong Kong Health Department
City of Milwaukee Health Department
United Kingdom Health Protection Agency

Results based on models of

United States
Washington, DC
Los Angeles County, CA
King County Summer Camp, WA
Seattle, WA
Milwaukee, WI
Allegheny County, PA
Dallas, TX
Washington State, county by county
Miami, FL
New York City
Hong Kong

1. Basta, N., Chao D.L., **Halloran, M.E**., Matrajt, L. and **Longini, I.M**.
   Strategies for pandemic and seasonal influenza vaccination of school children in the US. *American Journal of Epidemiology* 170, 679–686 (2009).

2. Cauchemez, S., Donnelly, C. A., Reed, C., Ghani, A. C., Fraser, C., Kent, C. K., et al. (2009). [**Burke**]
   Household transmission of 2009 pandemic influenza A (H1N1) virus in the United States.
   N Engl J Med, 361(27), 2619-2627.

3. **Cooley, P.**, Lee, B.Y., Brown, S.T., Cajka, J., Chasteen, B., Ganapathi, L., Stark, J.H., Wheaton, W.D., **Wagener, D.K.**, **Burke, D.S.**(2010)
   Protecting health care workers: a pandemic simulation based on Allegheny County. *Influenza and Other Respiratory Viruses*, 4, 61-72.

4. Cowling BJ, Lau EH, M Ip DK, Ho LM, Tsang T, Chuang SK, Leung PY, Lo SV, Liu SH, Riley S. [**Lipsitch**]
   School Closure and Mitigation of Pandemic (H1N1) 2009, Hong Kong. *Emerg Infect Dis.* 2010 Mar;16(3):538-41.

5. Dimitrov, N., Goll, S., Hupert, N., Pourbohloul, B. and **Meyers, L.A**. (2009). Optimizing tactics for use of the U.S. Antiviral Strategic National Stockpile for Pandemic (H1N1) Influenza, 2009. *PLoS Curr Influenza.* Nov 4: http://knol.google.com/k/optimizing-tactics-for-use-of-the-u-s-antiviral-strategic-national-stockpile?collectionId=28qm4w0q65e4w.1&position=19#

6. Epstein, JM. [**Burke**]
   Modeling to Contain Pandemics. *Nature*. vol 460/6 August 2009

7. Fraser, C., Donnelly, C. A., Cauchemez, S., Hanage, W. P., Van Kerkhove, M. D., Hollingsworth, T. D., et al. (2009). [**Burke**]
   Pandemic potential of a strain of influenza A (H1N1): early findings. *Science, 324*(5934), 1557-1561.

8. Goldstein E, **Lipsitch M**.
   Antiviral usage for H1N1 treatment: pros, cons and an argument for broader prescribing guidelines in the United States. PLoS Currents Influenza
   http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2770576/

9. Goldstein E, Apolloni A, Lewis B, Miller JC, Macauley M, **Eubank S**, **Lipsitch M**, Wallinga J.
   Distribution of vaccine/antivirals and the 'least spread line' in a stratified population. J R Soc Interface. 2009 Oct 14. [Epub ahead of print]

10. Goldstein E, **Lipsitch M**.
    H1N1 vaccination and adults with underlying health conditions in the US. PLoS Currents Influenza
    http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2781303/?tool=pmcentrez&report=abstract

11. Goldstein E, Miller JC, O'Hagan J, **Lipsitch M**.
    Predispensing of antivirals to high-risk individuals in an influenza pandemic.
    Influenza and Other Respiratory Viruses. 2010 Feb; 4(2): 101-112.

12. Goldstein E, Dushoff J, Ma J, Plotkin JB, Earn D, **Lipsitch M**:
    Reconstructing influenza incidence by deconvolution of daily mortality time series. Proc. Nat. Acad. Sciences USA 2009 Dec 22;106(51):21825-9

13. Lee, B. Y., Brown, S. T., Cooley, P. C., Zimmerman, R. K., Wheaton, W. D., Zimmer, S. M., et al. (2010). [**Burke**]
    A computer simulation of employee vaccination to mitigate an influenza epidemic. *Am J Prev Med, 38*(3), 247-257.

14. Lee, B. Y., Ercius, A. K., & Smith, K. J. (2009). [**Burke**]
    A predictive model of the economic effects of an influenza vaccine adjuvant for the older adult (age 65 and over) population. *Vaccine, 27*(16), 2251-2257.

15. Lee, B.Y., Mehrotra, A., Burns, R.M., Harris, K.M. (2009). [**Burke**]
    Alternative vaccination locations: who uses them and can they increase flu vaccination rates?
    Vaccine, 27(32):4252-4256.

16. Lee, B. Y., Brown, S. T., **Cooley, P.**, Potter, M. A., Wheaton, W. D., Voorhees, R. E., et al. (2009). [**Burke**]
    Simulating School Closure Strategies to Mitigate an Influenza Epidemic. *J Public Health Manag Pract*.

17. Lempel, H., Hammond, R.A. , Epstein, J.M. [**Burke**]
    Economic Cost and Health Care Workforce Effects of School Closures in the U.S. PLoS Currents: Influenza, RRN1051*.* October 1, 2009*. Submitted to British Medical Journal*

18. Lessler, J., Reich, N. G., Cummings, D. A., Nair, H. P., Jordan, H. T., & Thompson, N. (2009). [**Burke**]
    Outbreak of 2009 pandemic influenza A (H1N1) at a New York City school. *N Engl J Med, 361*(27), 2628-2636.

19. **Lipsitch M**, Hayden FG, Cowling BJ, Leung GM.
    How to maintain surveillance for novel influenza A H1N1 when there are too many cases to count.
    Lancet 2009; 374(9696):1209-11.

20. **Lipsitch M**, Lajous M, O'Hagan JJ, Cohen T, Miller JC, Goldstein E, Danon L, Wallinga J, Riley S, Dowell SF, Reed C, McCarron M.
    Use of cumulative incidence of novel influenza A/H1N1 in foreign travelers to estimate lower bounds on cumulative incidence in Mexico.
    PLoS One. 2009 Sep;4(9):e6895.

21. McCaw JM, Wood JG, McBryde ES, Nolan TM, Wu JT, **Lipsitch M**, McVernon J.
    [Understanding Australia's influenza pandemic policy on the strategic use of the antiviral drug stockpile.](#)
    Med J Aust. 2009 Aug 3;191(3):136-7.

22. Pourbohloul, B., Ahued, A., Davouidi, B., Meza, R., **Meyers, L.A**., *et al.* (2009). Initial human transmission dynamics of the pandemic (H1N1) 2009 virus in North America. *Influenza and other Respiratory Diseases* 3: 215-222.

23. Presanis A; **Lipsitch M**; De Angelis D; New York City Department of Health and Mental Hygiene, Swine Flu Investigation Team,; Hagy A; Reed C; Riley S; Cooper B; Biedrzycki P; Finelli L.
    The severity of pandemic H1N1 influenza in the United States, April – July 2009.
    PLoS Med. 2009 Dec; 6(12).

24. Reed C, Angulo FJ, Swerdlow DL, **Lipsitch M**, Meltzer MI, Jernigan D, et al.
    Estimates of the prevalence of pandemic (H1N1) 2009, United States, April–July 2009.
    Emerg Infect Dis, 2009 Dec. 15(12) 2004-2007.

25. Shaman J, Pitzer VE, Viboud C, Grenfell BT, **Lipsitch M**.
    Absolute Humidity and the Seasonal Onset of Influenza in the Continental United States.
    PLoS Biol. 2010 Feb. 8(2): e1000316.

26. Wallinga J, van Boven M, **Lipsitch M**.
    Optimizing infectious disease interventions during an emerging epidemic.
    Proc. National Acad. Sci., 2010 Jan. 107(2) 923-928.

27. White L, Wallinga J, Finelli L, Reed C, Riley S, **Lipsitch M,** Pagano M.
    Estimation of the Reproductive Number and the Serial Interval in Early Phase of the 2009 Influenza the Current Influenza A/H1N1. *Pandemic in the USA.*
    Influenza and Other Respiratory Viruses. 2009 Nov; 3(6): 267-276. PMCID: PMC2782458.

28. Wu JT, Leung GM, **Lipsitch M**, Cooper BS, Riley S.
    Hedging against antiviral resistance during the next influenza pandemic using small stockpiles of an alternative chemotherapy.
    PLoS Med. 2009 May 19;6(5):e1000085. Epub 2009 May 19.
    PubMed PMID: 19440354; PubMed Central PMCID: PMC2680070.

29. Wu JT, Lee CK, Cowling BJ, Yuen KY. [**Lipsitch**]
    [Logistical feasibility and potential benefits of a population-wide passive-immunotherapy program during an influenza pandemic.](#)
    Proc Natl Acad Sci U S A. 2010 Feb 16;107(7):3269-74. Epub 2010 Feb 1.

30. Yang, Y., Sugimoto, JD, **Halloran, ME**, Basta, NE, Chao, DL, Matrajt, L, Potter, G, Kenah, E, **Longini, IM**: The transmissibility and control of pandemic influenza A (H1N1) virus. *Science* 326, 729-33 (2009).

31. Zimmer, S. M., & **Burke, D. S.** (2009).
    Historical perspective--Emergence of influenza A (H1N1) viruses. *N Engl J Med, 361*(3), 279-285.

Submitted/In Press

Bansal, S., Pourbohloul, B., Hupert, N., Grenfell, B. and **Meyers, L.A**. (2010). T**he Shifting Demographic Landscape of Pandemic Influenza.** *PLoS ONE*. In press.

Basta, N., L. Matrajt, M. E.Halloran, E. Kenah, **Ira M. Longini, Jr.** , et al. Global Mitigation of Pandemic Influenza A (H1N1) with Vaccines. Authors: The WHO Informal Network for Mathematical Modelling for Pandemic Influenza H1N1 2009. In preparation.

Chao, D.L., **Halloran, M.E**. and **Longini, I.M**.: School opening dates predict pandemic influenza A (H1N1) epidemics in the USA (Submitted).

Chao, D.L., Basta, N., Dean, B., Matrajt, L., **Halloran, M.E**. and **Longini, I.M**.: Planning for control of pandemic influenza H1N1 in Los Angeles County and the US (Submitted).

Cowling BJ, et al. [**Lipsitch**]
Entry screening to delay local transmission of pandemic influenza A (H1N1). Submitted.

Cowling BJ, et al. [**Lipsitch**]
Estimating the effective reproduction number of pandemic influenza in real-time. Submitted.

Cowling BJ et al. [**Lipsitch**]
The interactions between population perceptions and health protective responses during the influenza A/H1N1 epidemic in Hong Kong: cross-sectional telephone surveys. Submitted.

Goldstein E, Cowling B, O'Hagan J, Danon L, Fang V, Hagy A, Miller JC, Reshef D, Robins J, Paul Biedrzycki P, **Lipsitch M**.
Oseltamivir for treatment and prevention of pandemic influenza A/H1N1 virus infection in households, Milwaukee, 2009. Submitted.

Hoen, A.G., Buckeridge, D.L., Chan, E., *et al.* (2010). [**Galvani/Meyers**]
Characteristics of US public schools with reported cases of novel influenza A/H1N1. *International Journal of Infectious Diseases.* In press.

Lau LLH, Cowling BJ, Fang VJ, Chan KH, Lau EHY, **Lipsitch M**, Cheng CKY, Houck PM, Uyeki TM, Peiris JSM, Leung GM. Viral shedding and clinical illness in naturally acquired influenza virus infections. *Journal of Infectious Diseases,* in press.

Matrajt, L. and **Longini, I.M**.: Critical immune and vaccination thresholds in heterogeneous populations. (In preparation).

Matrajt, L. and **Longini I.M**.: Evaluating vaccination strategies for pandemic influenza A (H1N1) when vaccine supply is limited (In preparation).

Parker, J and Epstein, JM. [**Burke**]
A Distributed Platform for Global-Scale Agent-Based Models of Disease Transmission. Forthcoming Transactions on Modeling and Computer Simulation (TOMACS), Association of Computing Machinery.

Sugimoto, J.D., Borse, N.N., Ta, M.L., Stockman, L.J., Fischer, G.E., Yang, Y., **Halloran, ME**, **Longini, I.M**. and Duchin, J.S.: The effect of age on transmission of clinical pandemic influenza A (H1N1) during an outbreak in a camp and households in Washington State, United States (Submitted).

The WHO Informal Network for Mathematical Modelling for Pandemic Influenza H1N1 2009 (Working Group on Data Needs).   (**Ira Longini** and **M Lipsitch**)   Studies needed to address public health challenges of the 2009 H1N1 influenza pandemic: insights from modeling. *PLoS Medicine* in press.

Zimmerman, RK, Lauderdale DS, Tan SM, Wagener, DK. Prevalence of High Risk Indications for Influenza Vaccine Varies by Age, Race, and Income. Submitted to Vaccine