ROLE OF TEMPERATURE, HUMIDITY AND RAINFALL ON INFLUENZA TRANSMISSION IN GUATEMALA, EL SALVADOR AND PANAMA

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ASTMH | 11/13/2012 | Atlanta

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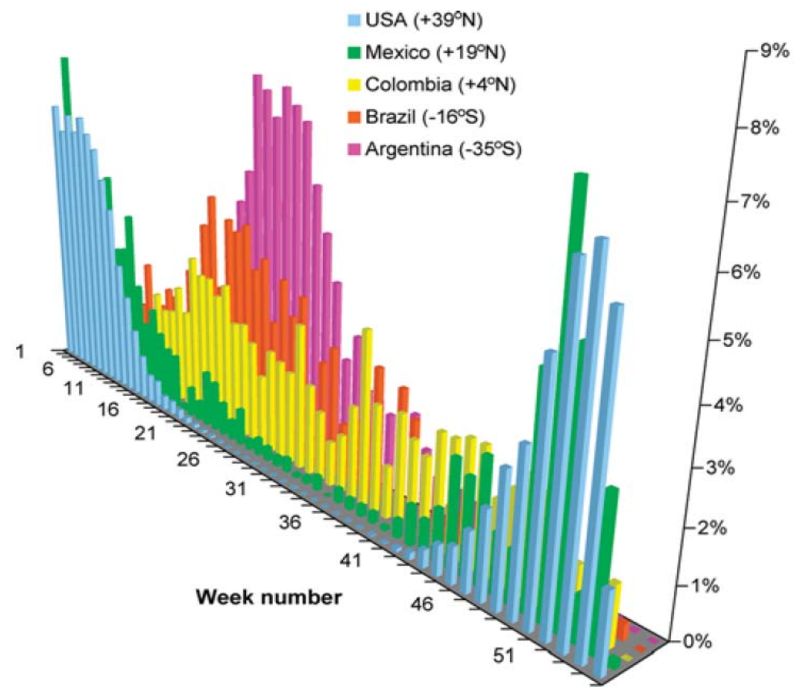
INTRODUCTION

Spatio-temporal pattern of influenza epidemics vary with latitude

- Temperate region
  - Distinct annual peak in winter
  - Cold and dry condition may bring seasonality
- Tropics
  - Less distinct seasonality
  - Often have multiple peaks
  - Coincides with rainy season



Source: Viboud et al. (2006). PLoS Medicine 3:e89

Southward migration in Brazil[1]

- From low population in the tropics
- To dense area with temperate climate

[1] Alonso et al. (2007). American Journal of Epidemiology 165: 1434

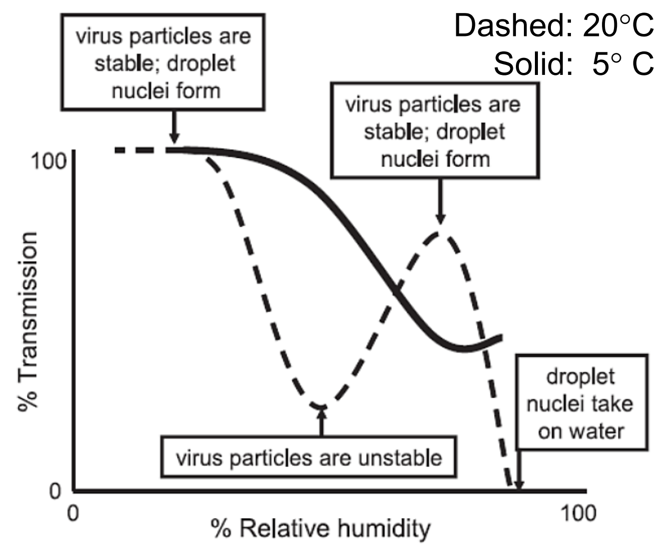
INTRODUCTION

FACTORS IMPLICATED IN INFLUENZA CIRCULATION

Virus Survival	Temperature	↓
	Humidity	↓
	Solar Irradiance	↓
Transmission	Temperature	↓
	Humidity	↓
	Vapor Pressure	↓
	Rainfall	↑
	ENSO	↑
	Holidays	↑
Host Susceptibility	Sunlight	↓
	Nutrition	↕

TEMPERATURE AND HUMIDITY

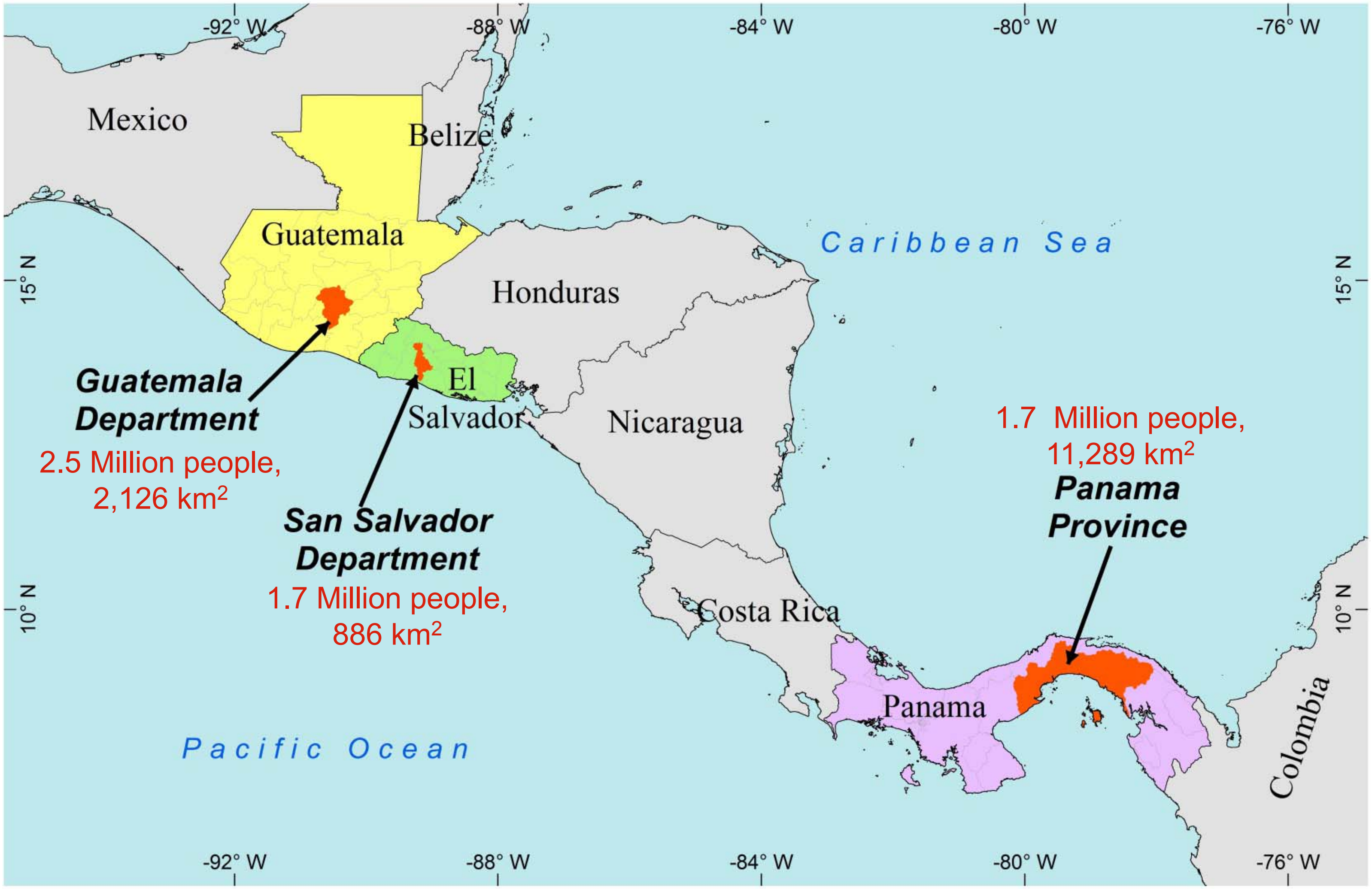
Animal study (Lowen et al. [1,2])



High temperature (30°C) blocks aerosol transmission *but not contact transmission*

[1]Lowen AC et al. (2007) PLoS Pathogen 3: 1470
[2]Lowen AC et al. (2008) J Virol 82: 5650

STUDY AREA

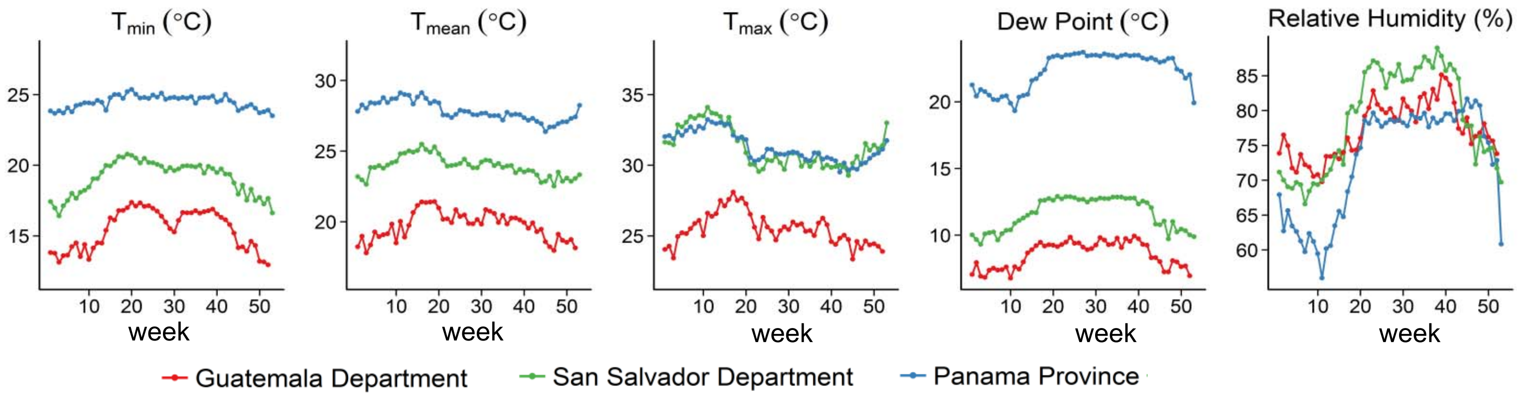


-92° W
-88° W
-84° W
-80° W
-76° W
Mexico
Belize
Guatemala
Honduras
El Salvador
Nicaragua
Costa Rica
Panama
Colombia
Caribbean Sea
Pacific Ocean
15° N
10° N
Guatemala Department
2.5 Million people, 2,126 km2
San Salvador Department
1.7 Million people, 886 km2
1.7 Million people, 11,289 km2
Panama Province

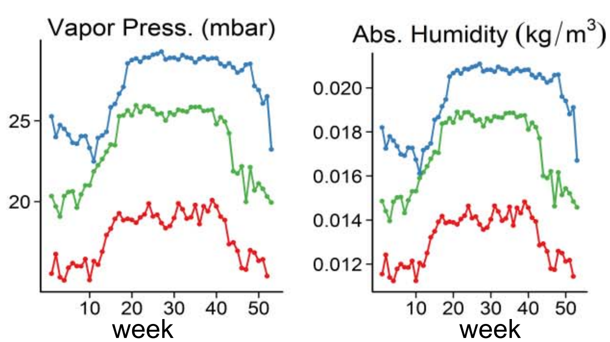
METEOROLOGICAL VARIABLE

Ground Station Data

- Country's Meteorological Agency (Guatemala and El Salvador)
- US National Oceanic and Atmospheric Administration (NOAA)

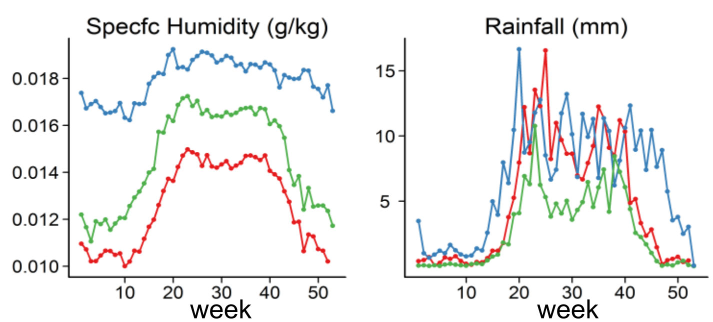


Derived/Calculated



Model-Based

NASA's Global Land Data Assimilation System (GLDAS)



Definition for humidity-related measures

Dew Point : Temperature at which the air can no longer hold all the water vapor it contains

Absolute Humidity: Amount of water vapor in a unit volume of air

Vapor Pressure : Partial pressure of water vapor

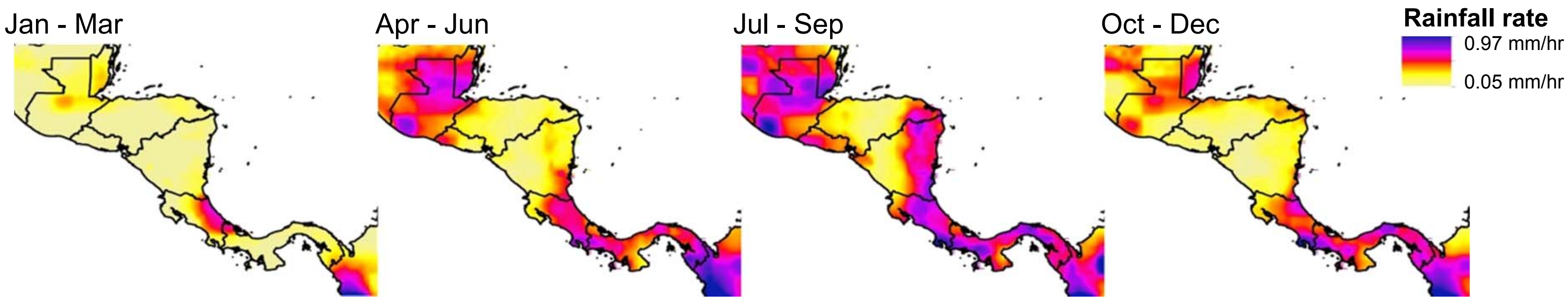
Specific Humidity: Ratio between mass of water vapor to the total mass of air

Relative Humidity: Ratio between the amount of moisture in the air to the amount of the air can "hold" at that temperature

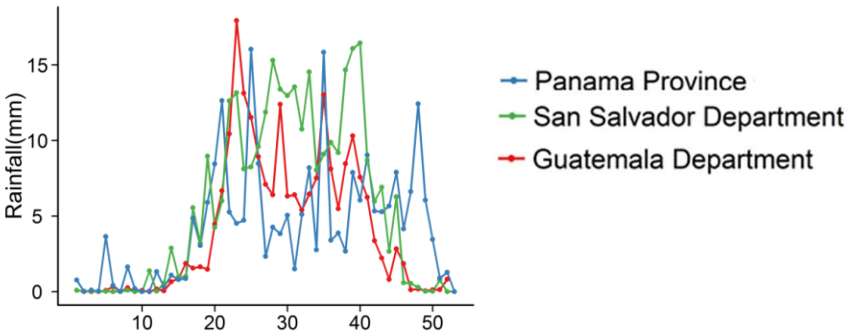
METEOROLOGICAL VARIABLE

Satellite Data

- Tropical Rainfall Measuring Mission (TRMM) – NASA and Japanese Aerospace Exploration Agency



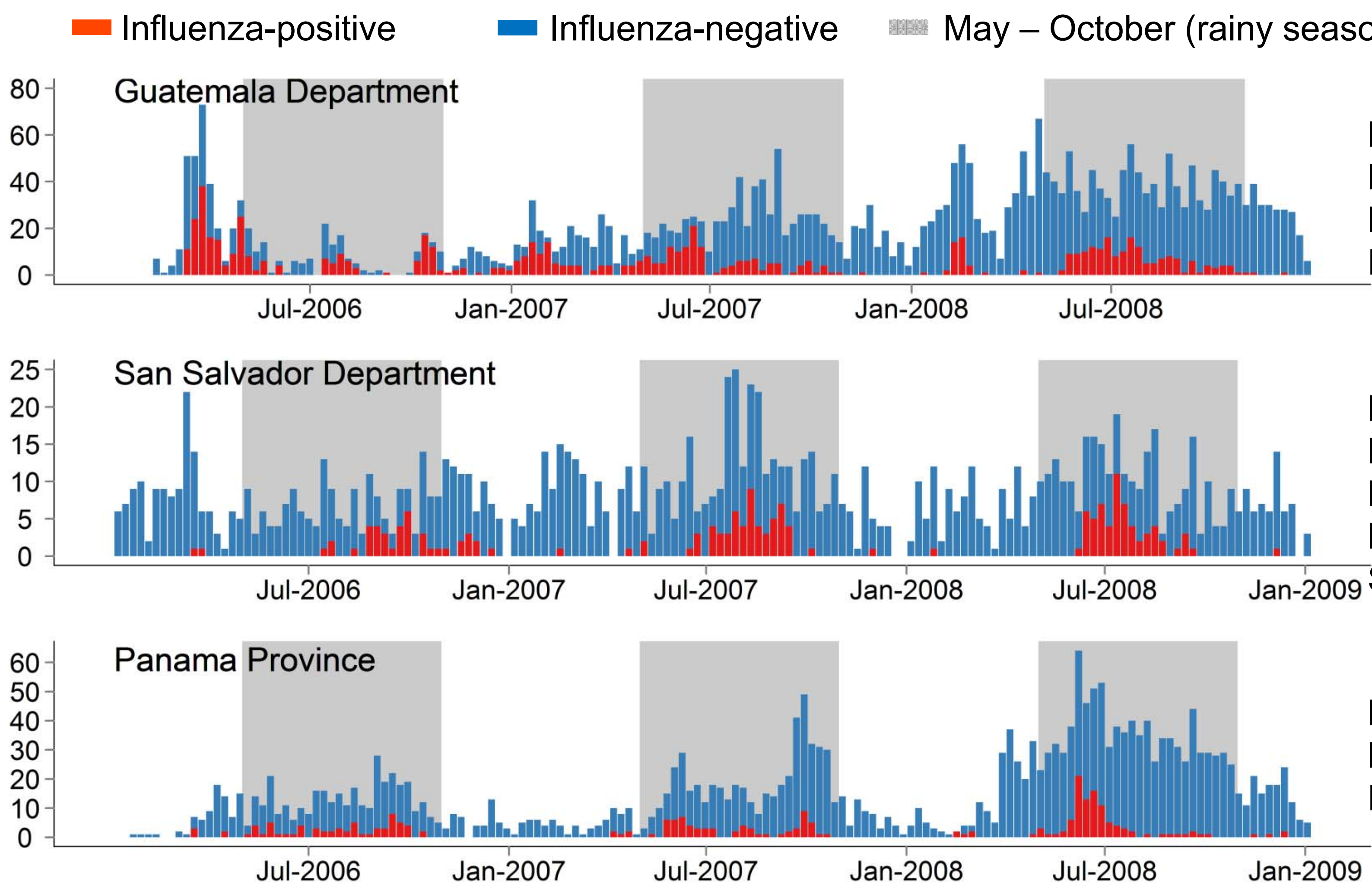
- Spatial resolution: 0.25° (~ 25 km)
- Averaged over pixels in which 10% or more of the area were covered by the region



All daily meteorological variables were averaged to obtain weekly composite (1- to 3-week averages were computed)

Lags from previous 1 to 4 weeks were also calculated

INFLUENZA DATA



Data source: National Laboratory of the Ministry of Public Health of Guatemala

Data source: Dr. Max Bloch National Laboratory of the Ministry of Health of San Salvador

Data source: Gorgas Memorial Institute for Health Studies

Higher influenza activity coincides with rainy season except for Guatemala which showed additional activities outside the season

METHOD

Quasi-Poisson regression

$$\ln(Y) = \mu + \alpha \cdot pop + \gamma \cdot month + \beta \cdot x_{met}$$

Where, Y= Influenza-positive samples

μ = Intercept

α,γ,β = coefficients

pop = population

x_{met} = meteorological factors

Divided meteorological variables into 3 categories in order to avoid collinearity

- Temperature: minimum, mean and maximum
- Humidity: relative, absolute & specific humidity; vapor pressure; dew point
- Rainfall: TRMM or GLDAS data set

Month variables were entered using stepwise method

Seek for the best meteorological 'averaging' period

(i.e. Average from current week to 2, 3 or 4 previous weeks)

Models were parameterized to each study site individually

Assessed model performance by pseudo-R^2

RESULTS

Best meteorological input combinations based on R^2

	β	95 % CI	p-value	R^2
Guatemala Department				0.64
Mean Temperature (0-3 wk ave)	0.95	(0.61, 1.29)	< 0.05	
Dew Point (0-3 wk ave)	0.15	(-0.33, 0.64)	0.4	
Rainfall GLDAS (0-3 wk ave)	0.09	(0.04, 0.14)	< 0.05	
Panama Province				0.51
Mean Temperature (0-3 wk ave)	1.22	(0.80, 1.64)	< 0.05	
Dew Point (0-3 wk ave)	0.16	(-0.11, 0.43)	0.15	
Rainfall GLDAS (0-3 wk ave)	0.16	(0.09, 0.23)	< 0.05	
San Salvador Department				0.64
Mean Temperature (1-4 wk ave)	0.17	(-0.4, 0.74)	0.5	
Specific Humidity (1-4 wk ave)	0.92	(0.63, 1.20)	< 0.05	
Rainfall TRMM (1-4 wk ave)	-0.02	(-0.11, 0.07)	0.7	

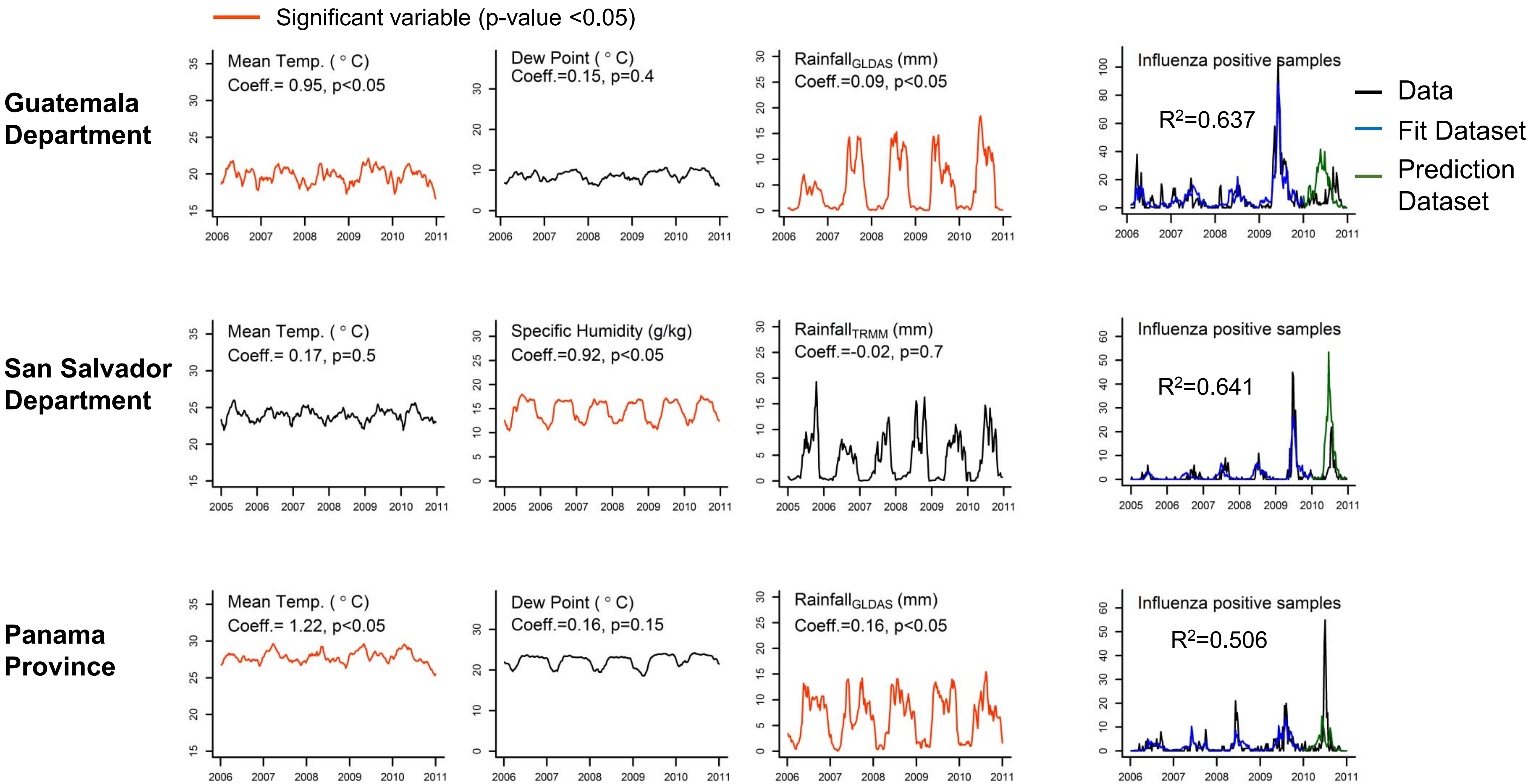
RESULTS

Sensitivity of influenza activities with respect to the meteorological variables

Meteorological variable increased	by	Changed the weekly influenza-positive sample by
Guatemala Department		
Mean temperature over the past 3 weeks	1°C	2.8 times
Mean rainfall over the past 3 weeks	5 mm	1.6 times
Panama Province		
Mean temperature over the past 3 weeks	1°C	3.4 times
Mean rainfall over the past 3 weeks	5 mm	2.2 times
San Salvador Department		
Specific humidity in the past 4 weeks	1 g/kg	2.5 times

RESULTS

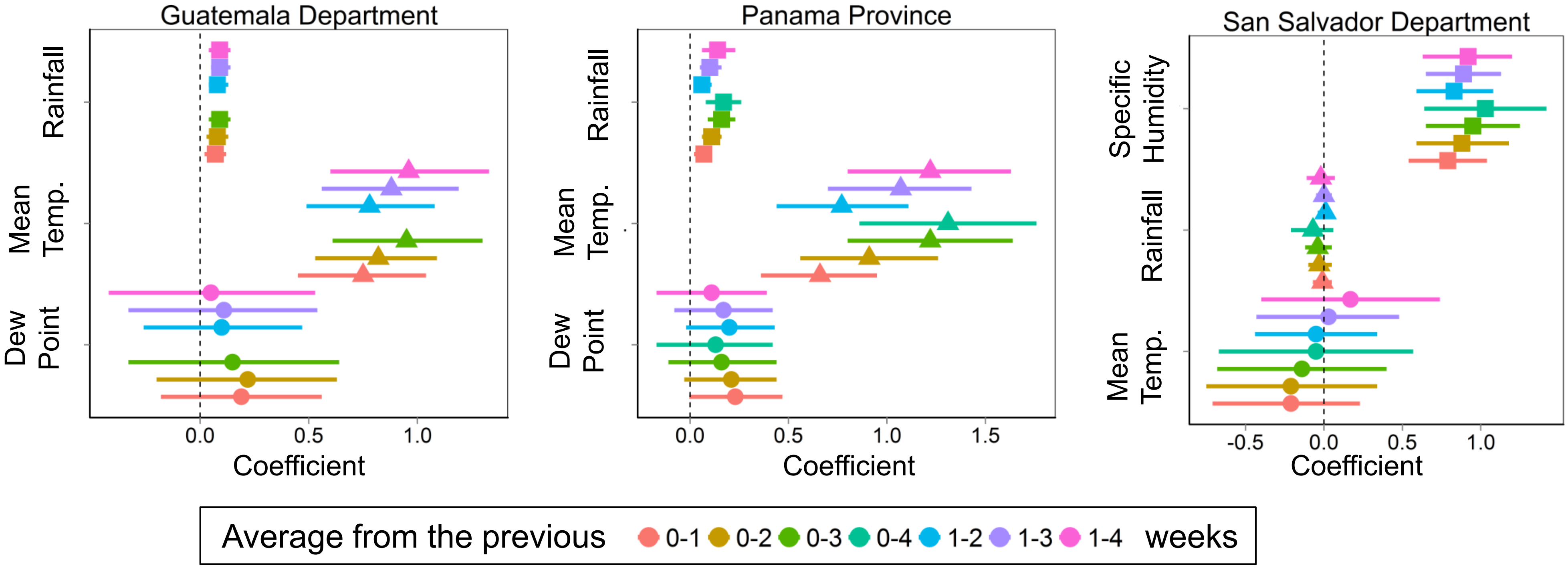
Meteorological parameters and modeled influenza-positive



RESULTS

Varying the 'averaging period' did not change the meteorological variables significance

Regression Coefficients and their 95% CI for the different averaging period

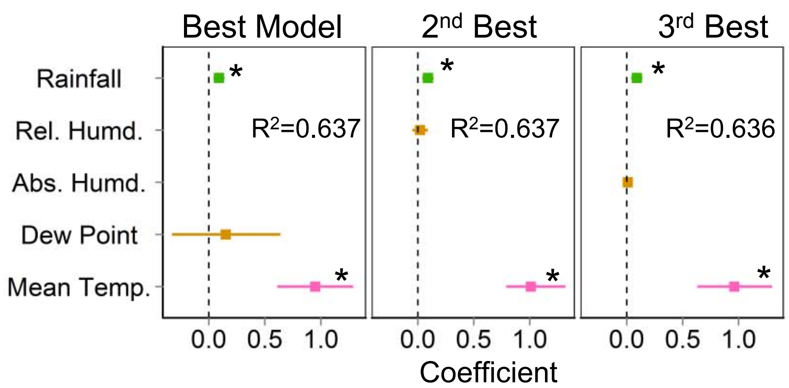


RESULTS

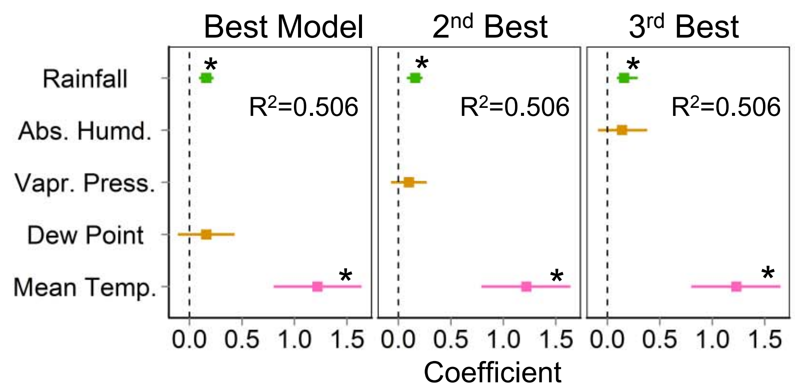
2^{nd} and 3^{rd} best models (based on R^2) showed the significant meteorological variables are still in the same category

- Indicates the robustness and stability of meteorological variable association with influenza

Guatemala Department

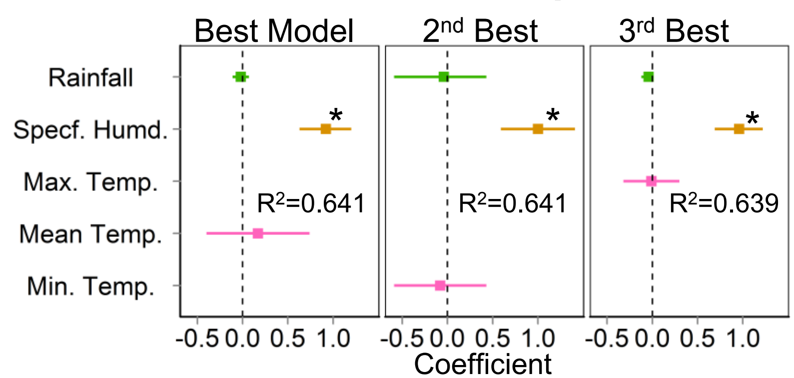


Panama Province



* Denotes significant variable ($p<0.05$)

San Salvador Department



RESULTS

Used influenza-positive proportion (rate) instead of counts

As compared to the regression with counts:

- The same category of meteorological variables remained significant for Guatemala and San Salvador
- Temperature was no longer significant in Panama
- Averaging period changed

	β	95 % CI	p-value	R^2
Guatemala Department				0.52
Mean Temp. (0-1 wk ave)	0.23	(0.09, 0.38)	0.002	
Specific Humd.(0-1 wk ave)	0.11	(-0.03, 0.24)	0.12	
Rainfall GLDAS (0-1 wk ave)	0.04	(0.002, 0.08)	0.04	
Panama Province				0.37
Mean Temp. (0-3 wk ave)	0.45	(-0.002, 0.9)	0.051	
Vapor Pressure(0-3 wk ave)	0.13	(-0.006, 0.3)	0.06	
Rainfall GLDAS (0-3 wk ave)	0.07	(0.009, 0.13)	0.025	
San Salvador Department				0.36
Min. Temp. (lag 2 wk)	-0.12	(-0.4, 0.2)	0.41	
Dew Point(lag 2 wk)	0.45	(0.16, 0.75)	0.003	
Rainfall TRMM (lag 2 wk)	0.001	(-0.05, 0.05)	0.95	

CONCLUSION

Higher influenza activity in the 3 Central American sub-divisions are associated with either humid, hot, or rainy condition

Results are consistent with other studies in the tropics[1-3] but are different from those in the temperate region

Most laboratory and animal studies showed increased influenza activity with lower temperature and humidity

- Our results may indicate that hot and humid condition provide uncomfortable condition that further promote indoor crowding and hence, contact transmission

The meteorological indicators can be used to estimate current and future influenza activity

1. Yang L, Chen PY, He JF, Chan KP, Qu CQ (2011). BMC Infectious diseases 11: 342
2. Chadha MS , Broor S, Gunasekaran P, Potdar V, Krishnan A (2012). Infl. & other resp. vir. 6: 196
3. Hampson AW (1999). Vaccine 17: 19

ACKNOWLEDGMENT

NASA Applied Sciences – Public Health and Air Quality Program

CDC Influenza Division: Jerry Tokars, Nancy Cox, Ann Moen and Joseph Bresee

CDC Central American Regional Office: Nelson Arboleda and Wilfrido Clara

Oscar Rene Sorto, **Ministry of Health of El Salvador, Health Surveillance Division**

Maria E. De Antiori, **Gorgas Memorial Institute of Health Studies, Panama**

Sidia Marinero, **Ministry of Environment and Natural Resources of El Salvador, Division of Meteorology**

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