Associations of Seasonal Influenza Activity with Meteorological Parameters in Temperate and Subtropical Climates: Germany, Israel, Slovenia and Spain

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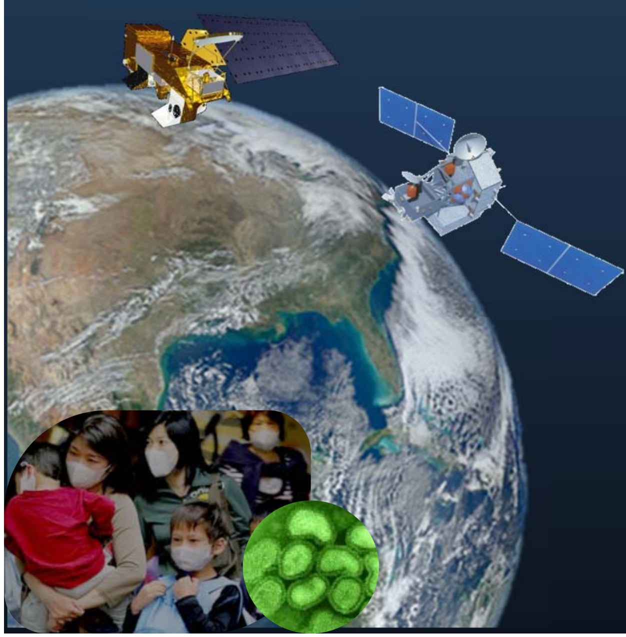

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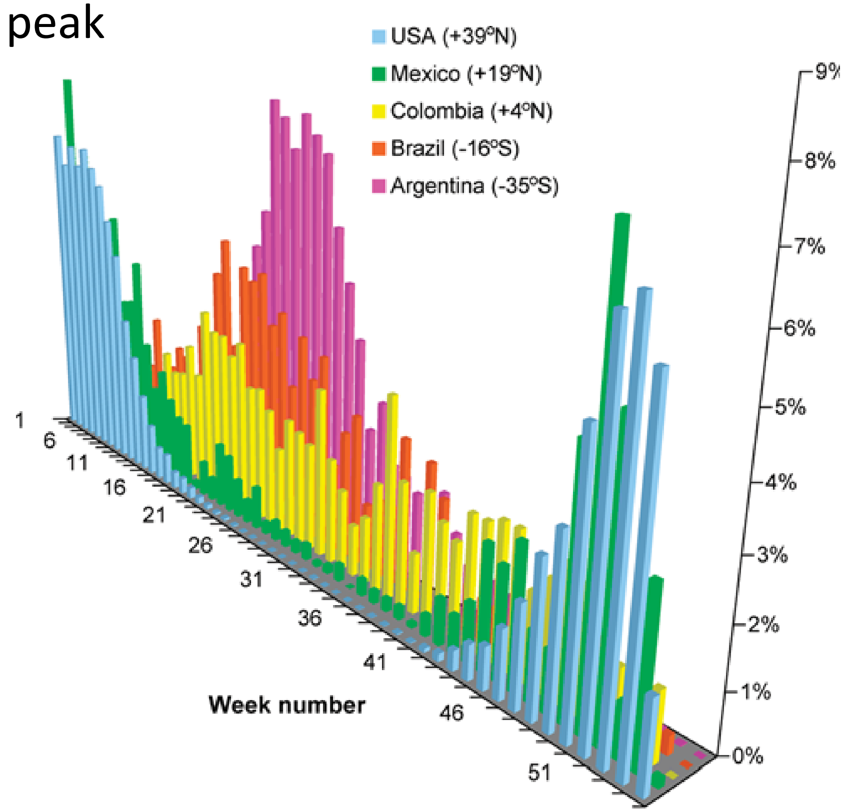
Seasonal Influenza

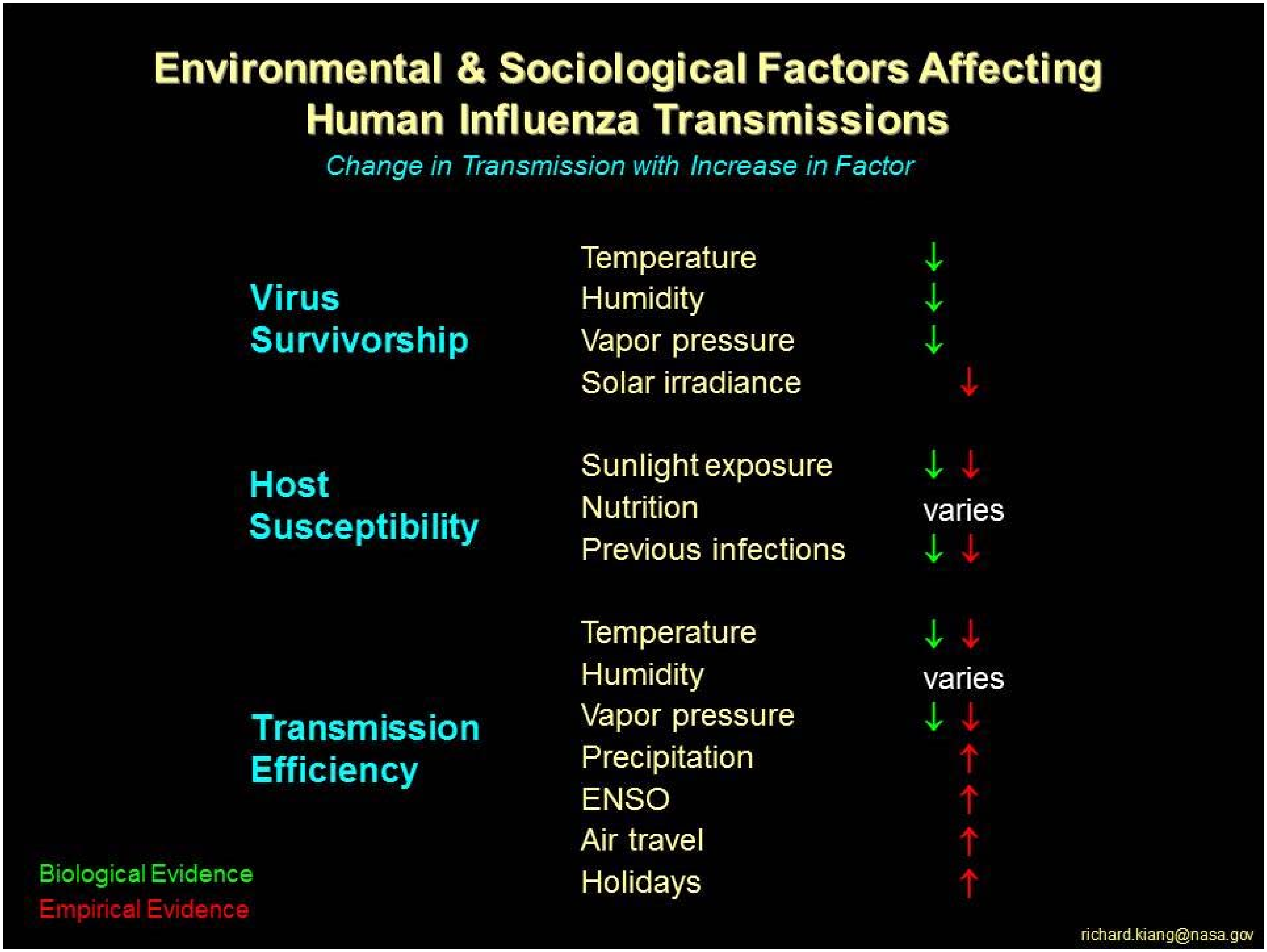
- Respiratory illness caused by influenza viruses
  - Influenza virus types: **A, B** and **C**
- Influenza viruses undergo frequent evolutionary changes
  - *Antigenic drift* results in a strain that is not recognizable by the body, may lead to a loss of immunity or vaccine mismatch
  - *Antigenic shift* results in a novel strain for human, causing pandemic
- Transmission: aerosol-borne, direct contact with infected, contact with contaminated objects
- Vaccination is the most effective method for prevention

Spatiotemporal Pattern

- Varies with latitude
- Temperate regions
  - Distinct annual oscillation with winter peak
- Tropics
  - Less distinct seasonality
  - Often more than 1 peak in a year
- Southward migration in Brazil from low-population area near equator to dense area with temperate climate [Alonso et al. 2007, Am. J Epi]
- Role of environmental and climatic factors

Viboud et al. (2006), PLoS Med. 3(4):e89




Environmental & Sociological Factors Affecting
Human Influenza Transmissions
Change in Transmission with Increase in Factor
Virus Survivorship
Temperature ↓
Humidity ↓
Vapor pressure ↓
Solar irradiance ↓
Host Susceptibility
Sunlight exposure ↓ ↓
Nutrition varies
Previous infections ↓ ↓
Transmission Efficiency
Temperature ↓ ↓
Humidity varies
Vapor pressure ↓ ↓
Precipitation ↑
ENSO ↑
Air travel ↑
Holidays ↑
Biological Evidence
Empirical Evidence
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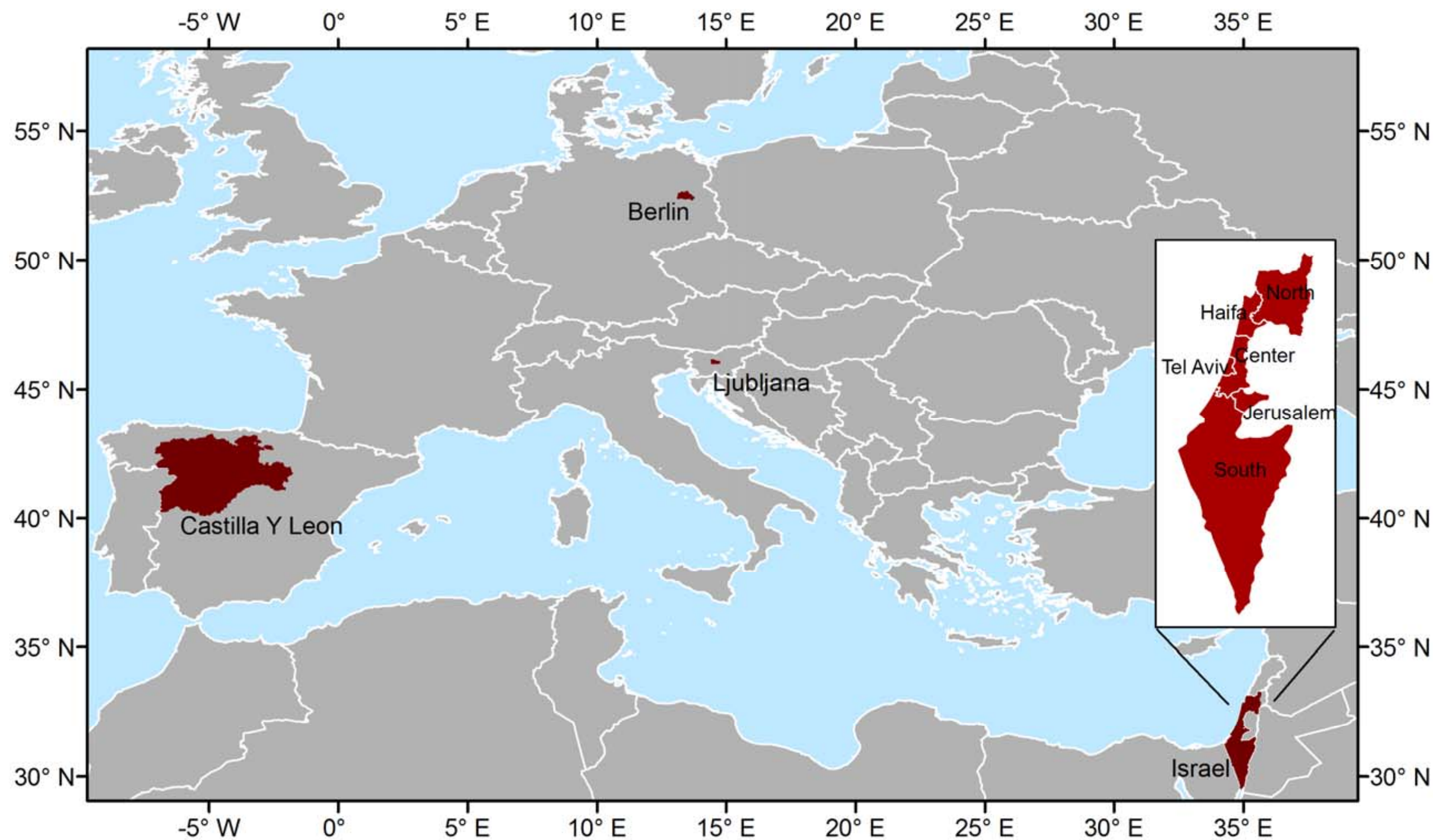
Study Objective

- Identify meteorological parameters associated with influenza activity
- Understanding influenza seasonality provides a basis on how pandemic influenza may behave
- Develop capabilities for short-term forecast of influenza activity as warranted by meteorological condition

Study Areas



-5° W
0°
5° E
10° E
15° E
20° E
25° E
30° E
35° E
55° N
50° N
45° N
40° N
35° N
30° N
Berlin
Ljubljana
Castilla Y Leon
Israel
North
Haifa
Center
Tel Aviv
Jerusalem
South

Climate Type in Study Areas

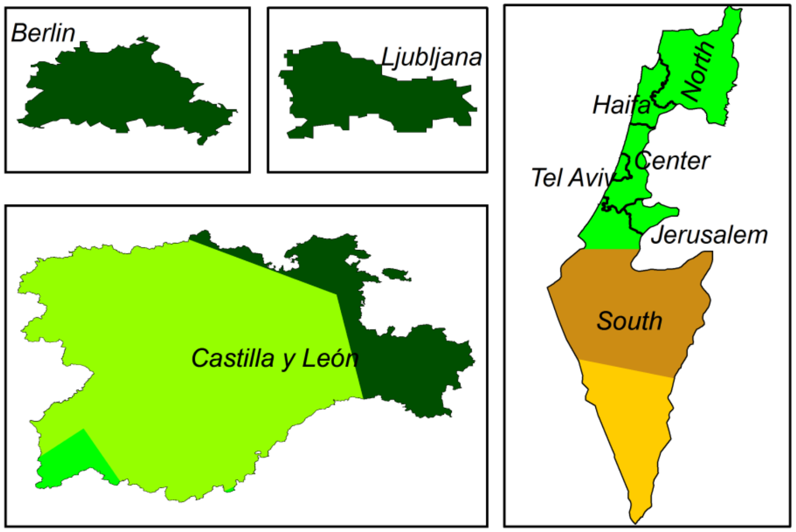
Köppen-Geiger Climate Classification

***Cfb*: Maritime Temperate, or Oceanic**

- Narrow annual temperature range
- Wet all year (lacks dry season)

***Csa* / *Csb:* Dry-Summer Subtropical, or Mediterranean**

- Summer month precipitation < 30 mm
- *Csa*: Hot summer, T > 22°
- *Csb*: Warm summer, T < 22°



***BSh:* Hot Semi-Arid , or Steppe**

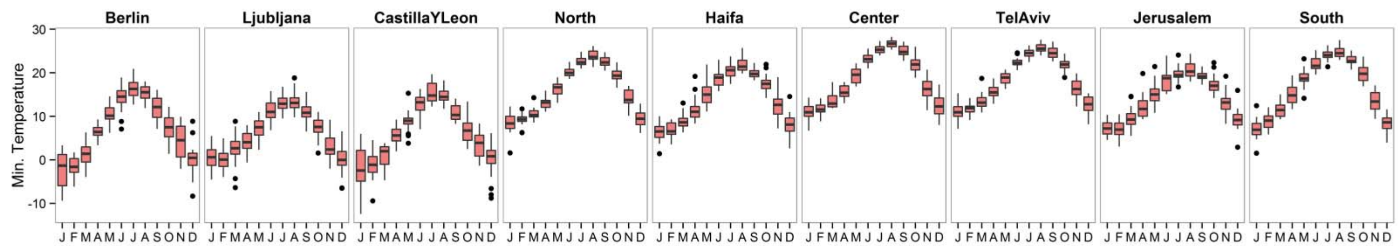
- Annual temperature ≥ 18°C

***BWh:* Hot Desert, or Arid**

- Annual precipitation < 250 mm

Meteorological Data

Ground station



NASA's

NASA's
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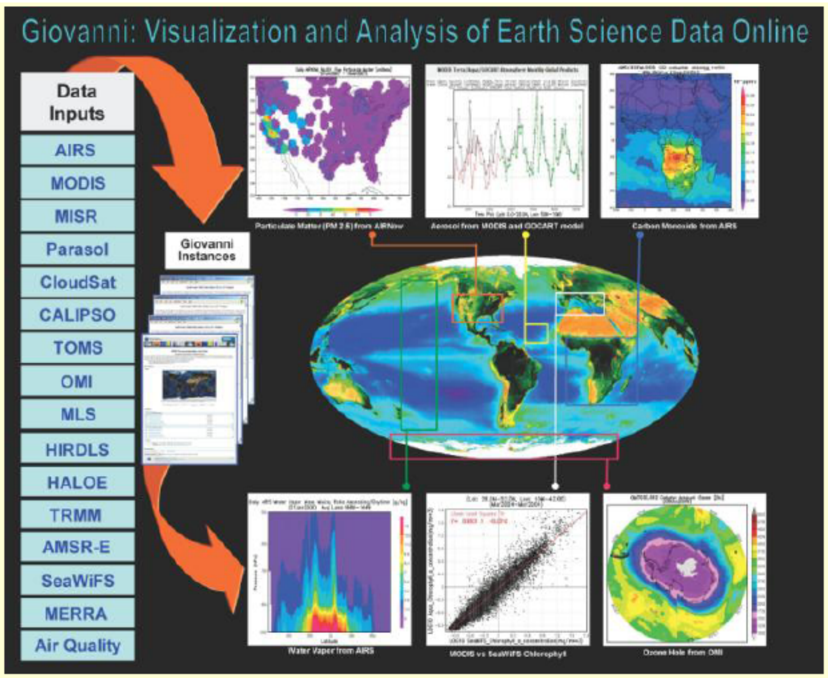
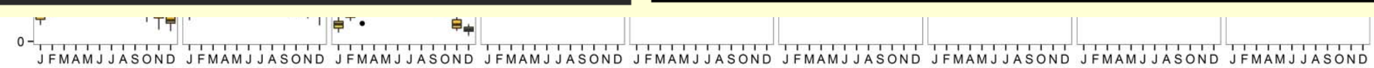
data



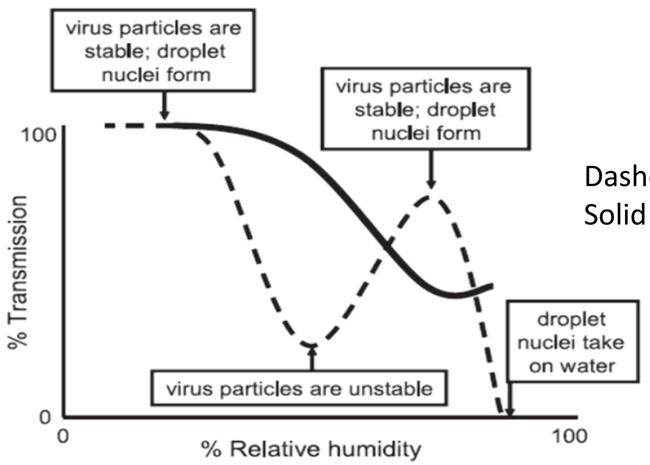
With Giovanni's data sets and user friendly analysis tools available on the World Wide Web to the whole world, it is possible for an increasing and broader audience to address issues in earth science without having a detailed knowledge of digital image processing and programming techniques- a Giovanni user.

- **It is a hands-on tutorial.**
- **Bring your own laptop and learn it on the spot.**
- **Start your own project.**



Brief Description on Humidity

- Measure of water content in the air
- Previous studies indicated
  - Bimodal relationship between influenza activity and relative humidity
  - Absolute humidity is a better predictor for influenza than relative humidity



Dashed: 20°C
Solid : 5° C

[Lowens et al., 2007]

- Relative Humidity

  Amount of water vapor in the air compared to the maximum amount of vapor that can exist in the air at the given temperature
- Absolute Humidity

  Mass of water vapor per unite volume of air
- Specific Humidity

  Ratio between mass of water vapor and the mass of air

Influenza Data

- Sentinel Surveillance

  Robert Koch Institute, Berlin, Germany

  Israel Center for Disease Control, Israel

  National Institute of Public Health Slovenia, Ljubljana, Slovenia

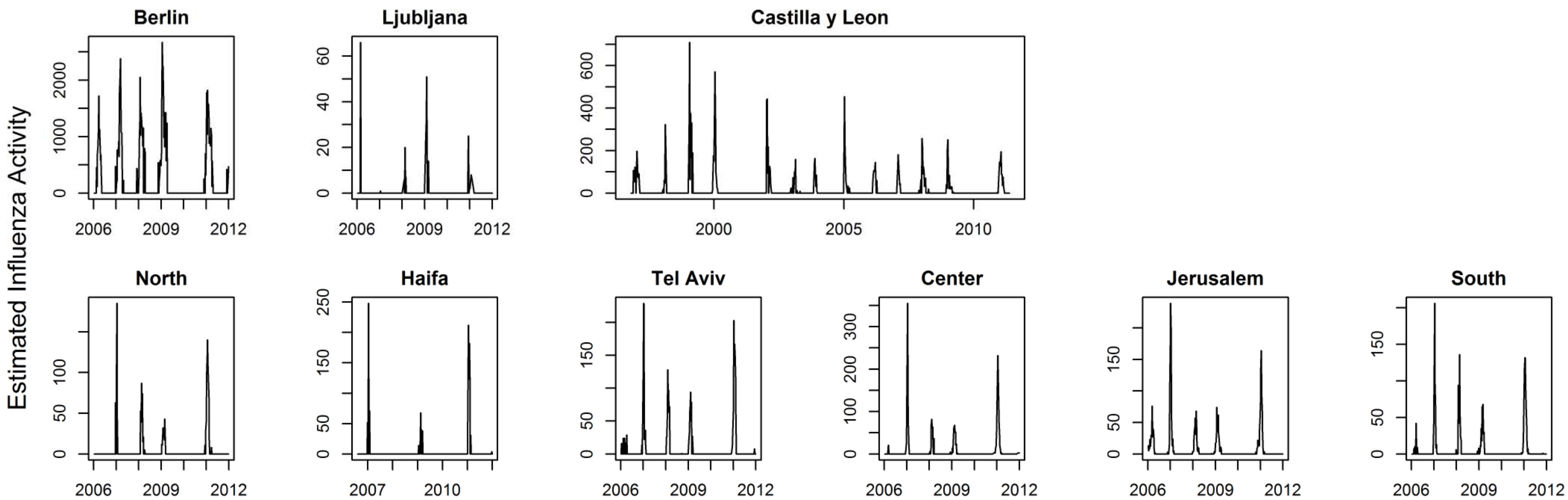
  Health Directorate, Health Department, Valladolid, Spain

  - Clinical Data
    - Influenza-Like-Illness (ILI), and/or Acute Respiratory Infection (ARI)
    - Case definition varies by country
    - ILI case definition recommended by WHO: acute respiratory illness with onset (the last 7 days) of fever (≥38°C) AND cough
  - Virological Data (Laboratory test)
    - ILI or SARI samples tested for influenza virus

Influenza Data

Weekly Influenza activity was estimated using:

$$y_t = \frac{\text{Influenza–positive samples}}{\text{Number of samples tested}} \times \frac{\text{ILI}}{\text{Population}}$$



- For Berlin, influenza activity was estimated from ARI data

Regression Model

Generalized Additive Model (GAM)

Estimated influenza activity at week t (y_t):

$$\ln(y_t) = \beta_0 + s(\ln(y_{t-2})) + s(sh_{1-4}) + s(rf_{1-4}) + s(srad_{1-4})$$

y_t	Estimated influenza activity at week t calculated from
β_0	Intercept
$s(x)$	Smoothed spline function of independent variable, x
$sh_{1\text{-}4}$	Specific humidity (in g/kg) averaged from the previous 4 weeks of t
$rf_{1\text{-}4}$	Precipitation (in mm) averaged from the previous 4 weeks of t
$srad_{1\text{-}4}$	Solar radiation (in W/m^2) averaged from the previous 4 weeks of t

- Temperature was excluded due to high correlation with specific humidity and solar radiation

Modeled Influenza Activity

Training data (year < 2010)

- All observations except for the final year was used to parameterize (or train) the model
- Excluded data during H1N1 pandemic year (May 2009 to May 2010)
- Model was trained individually to each area
- Inputs:
  - Specific humidity, rainfall and solar radiation (averaged over the previous 4 weeks)
  - Previous 1 or 2 weeks of influenza activity

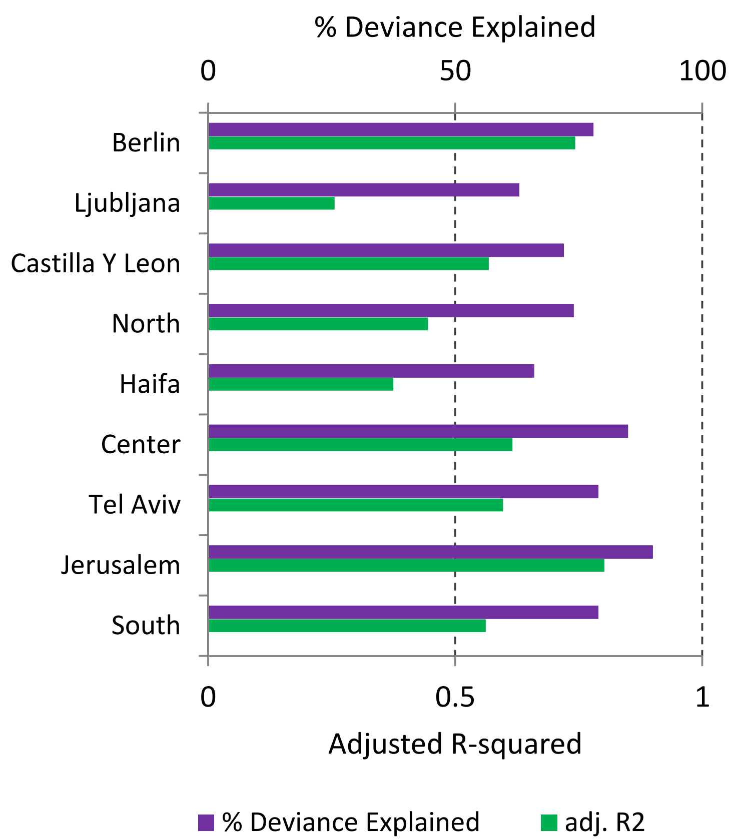
Modeled Influenza Activity

Predicted 2010/2011 Season

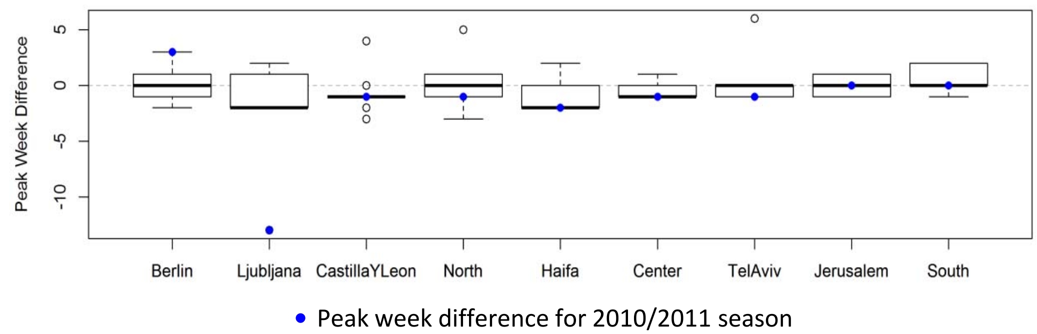
- The models closely followed the rise and fall of the epidemic curves in 6 out of the 9 study areas
- Peak timing could be predicted within 3 weeks of the observation (excluding Ljubljana)
  - Accurate prediction in Jerusalem and South
- Underestimated the amplitude of influenza activity in most areas

Model Performance

Goodness of fit



Accuracy of Peak Week Prediction



- Adjusted R2 ranged from 0.26 to 0.8 (mean = 0.55)
- 63% to 88% of deviance explained
- Predicted peak timing for training data was within 0 to 6 weeks of observation
- Lower model performance in Ljubljana and Haifa, where total number of specimens tested were lower as well

Meteorological Determinants

- Specific humidity is significantly associated with influenza activity in ALL regions
  - Inversed linear relationship
  - Highest contributor among meteorological variables (except for Spain)
- Influenza activity association with rainfall and solar radiation is region-specific. In general:
  - Nonlinear relationship with rainfall; inversed linear relationship with solar radiation

Meteorological variables effective degrees of freedom

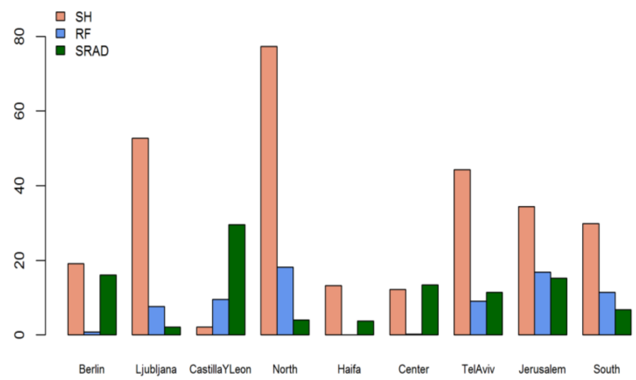
(effective number of parameters of the cubic spline smoother. A value of 1 typically indicates linear relationship)

	Specific Humidity	Rainfall	Solar Radiation
Berlin	1.66*	1	2.13*
Ljubljana	1*	1.35*	1
Castilla y León	1*	3.89*	2.57*
North	1*	2.95*	1*
Haifa	1*	1.02	1.68
Tel Aviv	1*	2.65*	1*
Center	1*	1	1.87*
Jerusalem	1*	2.18*	2.95*
South	1*	2.88*	1.89

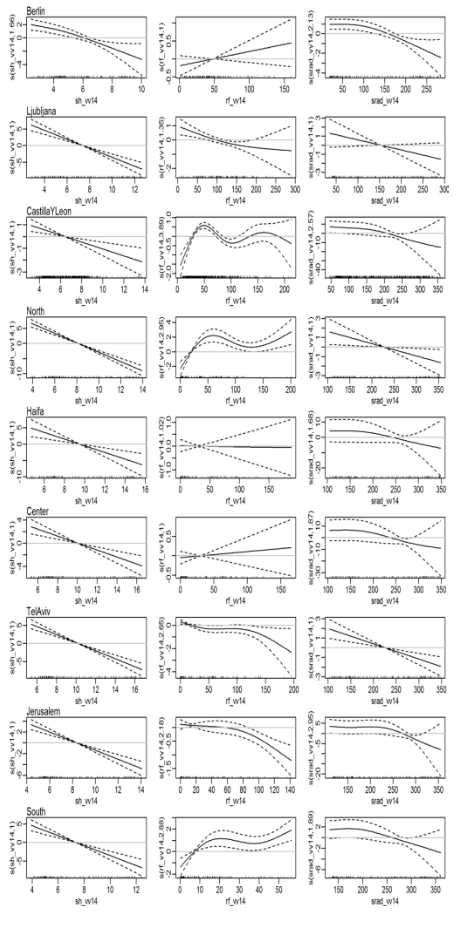
* Indicates significance (p-value < 0.05)

Meteorological variables Contribution to the model

(Calculated based on change in the explained deviance when the specified variable was removed)



Smoothed function for each meteorological variable



Improvement to Base Model

- Model determinants
  - Base model: Previous week(s) influenza activity
  - Full model: Previous week(s) influenza activity + meteorological variables
- Performance of full model is better than the base model as measured by Akaike's Information Criterion (AIC)

	Base Model			Full Model			% AIC Improved
	Adj. R^2	% Dev. Explained	AIC	Adj. R^2	% Dev. Explained	AIC	
Berlin	0.569	61	57708	0.743	78	32506	43.67
Ljubljana	0.111	23	1221	0.256	63	620	49.22
Castilla y León	0.441	57	25508	0.568	72	16926	33.64
North	0.183	30	3391	0.445	74	1350	60.19
Haifa	0.264	48	1932	0.375	66	1298	32.82
Tel Aviv	0.344	51	3834	0.597	79	1762	54.04
Center	0.56	76	1956	0.616	85	1306	33.23
Jerusalem	0.688	82	1511	0.802	90	980	35.14
South	0.499	62	2401	0.562	79	1431	40.4

Conclusion

- Significant association between influenza activity and specific humidity across temperate and subtropical climates
- Associations with precipitation and solar radiation were region-specific
- Results are consistent with other studies in the temperate regions
- Adding meteorological covariates improved historical data-based model performance
  - Could be used to enhance influenza surveillance system
  - Influenza activity can be predicted 2 weeks ahead

Acknowledgements

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THANK YOU