The impacts of increased atmospheric CO$_2$

First Order
Geophysical impacts on climate

Second Order
Impacts on biophysical systems (forests, oceans, grasslands)

Third Order
Impacts on vector-borne disease, extreme-heat deaths, famines

Fourth Order
Impacts on social and political systems

Latest CO$_2$ reading at Mauna Loa Observatory
November 16, 2017

405.71 ppm
Representative Concentration Pathways (RCPs)

RCP8.5
- No mitigation
- High emissions

RCP4.5
- Mitigation
- Lower emissions

Benefit: Avoided impacts

Adapted from B. O'Neill, NCAR
July 2017 – Climate scientists announce

By end of the century:

95% chance for 2°C warming
1% chance for <1.5 °C

Work done before the US pulled out of the Paris Climate Agreements

Does not account for decreasing price of solar

Nature Climate Change 2017
The two components of climate change

Changing patterns of climatic suitability

Increasing extreme weather events

Retreat of Arctic Sea Ice: NASA

Flash flooding in Toowoomba
Health impacts of climate change

- Severe Weather: Injuries, fatalities, mental health impacts
- Air Pollution: Asthma, cardiovascular disease
- Changes in Vector Ecology: Malaria, dengue, encephalitis, hantavirus, Rift Valley fever, Lyme disease, chikungunya, West Nile virus
- Increasing Allergens: Respiratory allergies, asthma
- Rising CO2 Levels: Extreme Heat
- Increasing Water Quality Impacts: Malnutrition, diarrheal disease
- Rising Temperatures: Cholera, cryptosporidiosis, campylobacter, leptospirosis, harmful fungal blooms
- CO2 Levels: Environmental Degradation
- Forced migration, civil conflict, mental health impacts
- Heat-related illness and death, cardiovascular failure

Courtesy of George Luber, CDC
Clear links: extreme heat and mortality

Heat wave kills more than 1,100 in India

By Harmeet Shah Singh and Reshabh Pratap, CNN
Updated 5:52 PM ET, Thu May 28, 2015

France heat wave death toll set at 14,802

PARIS (AP) — The death toll in France from August’s blistering heat wave has reached nearly 15,000, according to a government-commissioned report released Thursday, surpassing a prior tally by more than 3,000.

Death rate doubles in Moscow as heatwave continues

6 March 2012 | Europe

Moscow’s health chief has confirmed the mortality rate has doubled as heatwave and wildfire smog continue to grip the Russian capital.

Examining Heat-Related Deaths During the 1995 Chicago Heat Wave

Cook County, July 11–27, 1995:
Excess deaths compared with this time period during an average year: about 700
Deaths classified as “heat-related” on death certificates (not shown here): 465

This graph shows data for the Chicago Metropolitan Statistical Area. During the 1995 Chicago heatwave, 465 heat-related deaths were recorded on death certificates in Cook County. Later studies found that approximately 700 more deaths occurred during this period compared to average daily death rates for this area.

Data sources:

For more information, visit U.S. EPA’s “Climate Change Indicators in the United States” at www.epa.gov/climatechange/indicators.
Impacts of extreme heat are not evenly spread

Relative Risk of Heat Related Mortality
Houston Texas

911 Heat Distress Calls  Urban Heat Island  Heat Health Outcomes

Income  Race and Ethnicity  Use of Air Conditioning

Heaton et. al. 2014
Infections and Climate Change

RELATIONSHIP STATUS: ITS COMPLICATED
Projecting long-term epidemic potential

**Understand the system**
What is the process that climate/weather intersect with social dynamics to influence infectious disease potential?
- Determine patterns of seasonality
- Conduct correlations across differing geographies
- Laboratory experimentation

**Mitigating factors**
Given exposure, who are the vulnerable?
- Examine risk factors for the transmission
- Determine the current and projected distribution of these risk factors

**Compile into projections**
If we drive process models with projected climate data coupled with data on the human dimension, what happens?
- Determine complex interactions among all the determinants of the process and the potentially mitigating risk factors
Susceptibility and mode of transmission

- Sexually transmitted
- Respiratory
- Water-borne and Vector-borne
Infections linked to extreme weather events

**DROUGHTS**
- Concentrating pathogens
  - Cholera
  - Typhoid
  - West Nile
- Increased Susceptibility
  - Undernutrition
  - Measles
  - Respiratory Infections

**FLOODS**
- Dissemination via water
  - Cholera
  - Shigellosis
  - Leptospirosis

**FLOODS**
- Vector-Reservoir Habitat
  - Malaria
  - Schistosomiasis
  - West Nile

**FLOODS-HURRICANE**
- Crowding/ Low infrastructure
  - Respiratory Infections
  - Meningitis
  - TB
CASE STUDY: HURRICANE KATRINA

- August 29, 2005
- 1833 deaths
- $41.1 billion in claims
- Infections
  - 22 Vibrio cases
  - 20 clusters of diarrheal illness in evacuation centers
  - West Nile Virus 2x higher
Case Study: Hurricane Matthew Haiti

- October 4, 2016
- >1000 killed directly
- $1.1 billion in estimated damage
- Infection
  - Over 50% increase in cholera cases
  - Others? Unknown
Transmission risk in a given geographic area

- Risk of Transmission
- Detection/Response infrastructure
- Human Environment: Mobility Behavior infrastructure
- Human – Natural Environment interactions:
- Environmental Suitability
Aedes aegypti aka “The Yellow Fever Mosquito”

- Highly adaptable
- Human commensal
- Day-biter (bednets less useful)
- Transmits
  - Yellow fever virus
  - Dengue viruses
  - Chikungunya virus
  - Zika virus
  - Mayora virus
Distribution of dengue virus

Source: Bhatt et al. 2013, Nature 496, 504–507
Aedes aegypti infest urban areas throughout the Arizona-Sonoran Desert region.
Arizona, Estados Unidos

Sonora, México

Social factors play a role in differential transmission
Transmission of dengue in Arizona and Sonora


Sonora – N-S gradient
Arizona – No transmission

Higher transmission
Social factors
  Lower education
  Higher population density
  Distance from highway
Climate factors
  Higher Precipitation
  Higher Minimum temperature
Disparity in dengue transmission


Incidence per year (by 100,000)

<table>
<thead>
<tr>
<th>Year</th>
<th>Hermosillo</th>
<th>Nogales</th>
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<tbody>
<tr>
<td>2006</td>
<td>22.6</td>
<td>1.4</td>
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<td>2007</td>
<td>15.4</td>
<td>0.5</td>
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<tr>
<td>2008</td>
<td>92.0</td>
<td>No cases</td>
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<tr>
<td>2009</td>
<td>22.2</td>
<td>1.9</td>
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<tr>
<td>2010</td>
<td>504.0</td>
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<td>2011</td>
<td>26.3</td>
<td>1.0</td>
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<tr>
<td>2012</td>
<td>12.3</td>
<td>No cases</td>
</tr>
<tr>
<td>2013</td>
<td>33.1</td>
<td>1.9</td>
</tr>
<tr>
<td>2014</td>
<td>120.6</td>
<td>6.6</td>
</tr>
<tr>
<td>2015</td>
<td>88.1</td>
<td>1.9</td>
</tr>
</tbody>
</table>

No locally acquired dengue transmission
Abundance of *Ae. aegypti* old enough to transmit disease varies by city and year.
Coupled factors enhancing expansion

- Increasing Urbanization
- Increasing Habitat
- Increasing Travel
- Increasing Trade
Pathogen Introduction: Focus on Mobility

Likelihood of traveler/ migrant contracting pathogen

Likelihood of infected traveler/ migrant introducing spread to home country

Short-term travel
- Business travel
- Vacationers

Mid-range
- Project work
- Students

Permanent Resettlement
- Refugees
- Immigration
Case Study: Chinese Construction Sites in Sri Lanka

- Colombo, Sri Lanka, November 6th, 2017
- 3500 Chinese laborers
  - Risk factors
    - Previously unexposed to dengue
    - Construction created breeding sites

Increasing habitat suitability to *Ae. aegypti* in coming decades for southern China
Coming soon: Port City
Long term predictions to early warning and early detection

Use in public health response and planning

Uncertainty

Cases

Long-term prediction
Driven by:
- climate change scenarios
- Population projections

Early warning systems
Driven by:
- seasonal forecasts
- current census information

Early detection
Sources:
- syndromic data mining
- HC-based
- CBP

Traditional surveillance

Sources:
- syndromic data mining
- HC-based
- CBP

Time

50yrs 20yrs 10yrs 5yrs 1yr 6mo 3mo 1mo onset peak end
Integration of data

- As more about the dynamics are learned in the field they are integrated into a dynamic model of disease risk
Long-term Predictions: Projected global range of *Ae. aegypti*, 2061-2080

b) 2061-2080 (RCP4.5 minus Reference)

c) 2061-2080 (RCP8.5 minus Reference)

(Monaghan et al. 2016, Climatic Change)
Zika Risk in CONUS

- Weather-driven mosquito models with:
  - travel,
  - socioeconomic conditions
  - virus history
- Required rapid analysis
- Designed for widespread dissemination to stakeholders and the public.
- One time assessment
- Used climate not current weather

Monaghan AJ, Morin CW,....Ernst K. PLOS Currents (March 2016)
Dengue in Brazil
- Tweets strongly correlated with case reports
  - County level
  - City level
- Nowcasting
- Forecasting up to 8 weeks

http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0005729
Early Detection: Kidenga, self-reported syndromic information

USER GENERATED

CONFIRMED HEALTH DEPARTMENT DATA

Confirmed cases in TX

Likely Mosquito Areas

- Chikungunya
  - Williamson: 1

Dengue
- Brown: 1
- Dallas: 2
- Gregg: 1
- Harris: 1
- Lubbock: 1

Recent Cases

(Ae. aegypti)
(Ae. albopictus)
Climate change will influence many health outcomes.

Complex relationships between environmental-human-pathogen factors will vary by region.

Risk will be modified by the vulnerability of the populations exposed to the pathogens.

Systems that can readily and reliably predict and detect transmission are needed.

Mobilization of resources early in an epidemic will greatly reduce transmission.
References


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