Assessment of climate bridges in the world air traffic network using centrality measures

EMS2019 - Kopenhagen

by P. Hoffmann et al.

7th October 2019
1. Introduction

1.1 InfectControl2020

**aim:** developing strategies for dealing with infectious diseases in the 21st century

**Consortium:** prioritization of relevant topics (1) agriculture and veterinary medicine (2) climate, mobility infrastructure (3) medical research and care (4) patient and public (prevention - diagnostic - therapy)
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1. Introduction

1.2 Climate & Pathogens

partners: Charité Berlin, Robert-Koch-Institute, PIK

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**aim:** interruption of transmission pathways of infectious diseases in air traffic

*Transsectoral Research:* (1) material scientists - *surfaces* (2) architects - *airport building* (3) climatologists - *climate bridges to infection bridges* (4) epidemiologists - *literature review & consulting* (5) molecular biologists - *screening tests* (6) industrial partners - *sanitary solutions*
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2. Datasets

Open Flight Data and Populations:
* (1) airports (2) static daily flight connections

Daily Gridded Climate Data (0.5°x0.5°): 1979-2016
* daily maximum temperature (daily water vapor pressure)

Climate Scenarios: 2041-2070 (RCP85)
* CMIP5 bias-adjusted (ISI-MIP)
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2.1 Sub-Flight Network of 99 Airports

Fig.: (1) 99 selected Airports (2) population (3) 3255 daily flight connections (4) climate data - not everyone with everyone
3. Methods

3.1 Data Processing (GraphML)

**Nodes:** Airports (99)

```xml
<node id="ATL">
  <data key=city>Atlanta</data>
  <data key=date>2016-12-29</data>
  <data key=lat>33.636</data>
  <data key=lon>-84.428</data>
  <data key=population>1.839</data>
  <data key=tasmax>15.036</data>
  <data key=pr>5.207</data>
</node>
```

**Edges:** Flights (3255)

```xml
<edge source="ATL" target="MCO">
  <data key=weight>0.311</data>
</edge>
```

- (1) calculating daily climate bridge and network measures
- (2) aggregation to monthly data to study seasonality
- (3) analyzing trends and climate change signals
- (4) input for propagation calculations
3. Methods

3.1 Data Processing (GraphML)

<table>
<thead>
<tr>
<th>nodes: Airports (99)</th>
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<tbody>
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3.2 Definition: Climate Bridge

**Climate Bridge Transfer Function**

\[
f(t) = \frac{1}{1 + \exp[-c \cdot (t - 27)]}
\]

**Fig.:** The weight of flight connections dependent on daily maximum temperature at two connected airports (nodes): source and target.
3. Methods

GTX visualization of climate bridges for FRA

winter conditions

summer conditions
3. Methods

3.3 Definition: Network Measures

**Degree centrality** assigns an importance score based purely on the number of links (flight connection) held by each node (airport). For finding very connected and popular nodes, airports those are likely to hold most information or airports those can quickly connect with the wider network.

**Betweenness centrality** measures the number of times a node (airport) lies on the shortest path between other nodes (airports). This measure shows which nodes (airport) act as ‘bridges’ between nodes (airports) in a network. It does this by identifying all the shortest paths and then counting how many times each node falls on one.

\[ g(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}} \]
3. Methods

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**Socnetv: unweighted network**

**Degree Centrality**

1. DXB (Dubai)
2. LAX (Los Angeles)
3. JFK (New York)

**Betweenness Centrality**

1. PEK (Peking)
2. AMS (Amsterdam)
3. LHR (London)

**DXB:** most flights

**PEK:** shortest flight connections between other airports
3. Methods

3.4 From Climate to Infection Bridges

Compartmen tal model in epidemiology

**SEIR:** Susceptible - Exposed - Infectious - Recovered - model

transmission rate = climate bridge (infection bridges)
4. Results

4.1 Assessment of Airports (interactive sorted table)

Assessment of Airports: 1979-2016 / 2041-2070 (RCP85)

<table>
<thead>
<tr>
<th></th>
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<td>0.053</td>
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<td>0.088</td>
<td>0.012</td>
<td>14.3</td>
<td>16.6</td>
<td>2.338</td>
<td>744</td>
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<td>0.021</td>
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<td>0.000</td>
<td>15.5</td>
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<td>5.066</td>
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<td>116.585</td>
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<td>41.696</td>
<td>7.543</td>
<td>0.103</td>
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<td>-0.003</td>
<td>17.9</td>
<td>21.1</td>
<td>3.262</td>
<td>564</td>
<td>611</td>
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ranking of airports by columns ...
4. Results

**Summary**

<table>
<thead>
<tr>
<th>#</th>
<th>DG 1979-2016</th>
<th>DG 2041-2070</th>
<th>△</th>
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<tr>
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<tr>
<td>FRA</td>
<td>9.</td>
<td>7.</td>
<td>4.</td>
</tr>
</tbody>
</table>

1. ranking of airports by the network measure: weighted degree centrality
2. comparing recent (1979-2016) and future (2041-2070) conditions
3. What does it means for Frankfurt (FRA)?
4. Results

4.2 Statistics for FRA

(1) Temperature: seasonal shift to higher temperatures
(2) Degree Centrality: climate effect in the order of additional 10 flights
(3) Betweenness Centrality: increasing seasonality
4. Results

4.3 Outbreak

Fig.: Number of days until outbreak (source=BOM) reaches (target=FRA) over the initial date. An outbreak in spring shows the shortest time of less than 100 days.
5. Final Remark

By the definition of climate bridges in the air traffic network every single flight gets a weight according to the prevailing weather conditions.

This changes the network characteristics and the centrality measure of airports in the entire network.

The possible effect on human and human health can be estimated.
5. Final Remark

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The possible effect on human and human health can be estimated.
Thank you for your attention!