Severe airport sanitarian control could slow down the spreading of COVID-19 pandemics: Study cases of Brazil and Mexico

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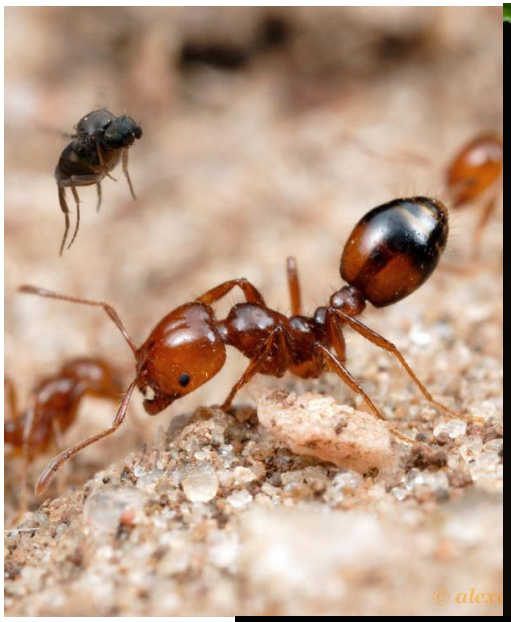
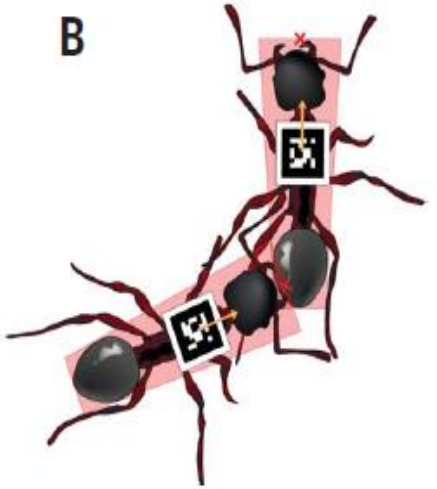
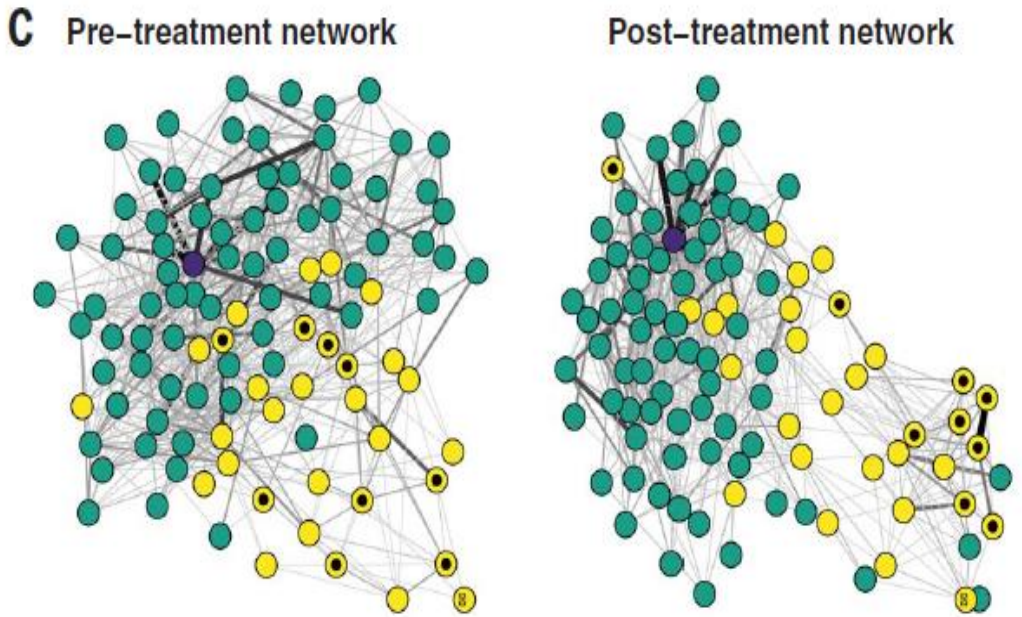
Social immunity: an inspiration our policy makers ignored!

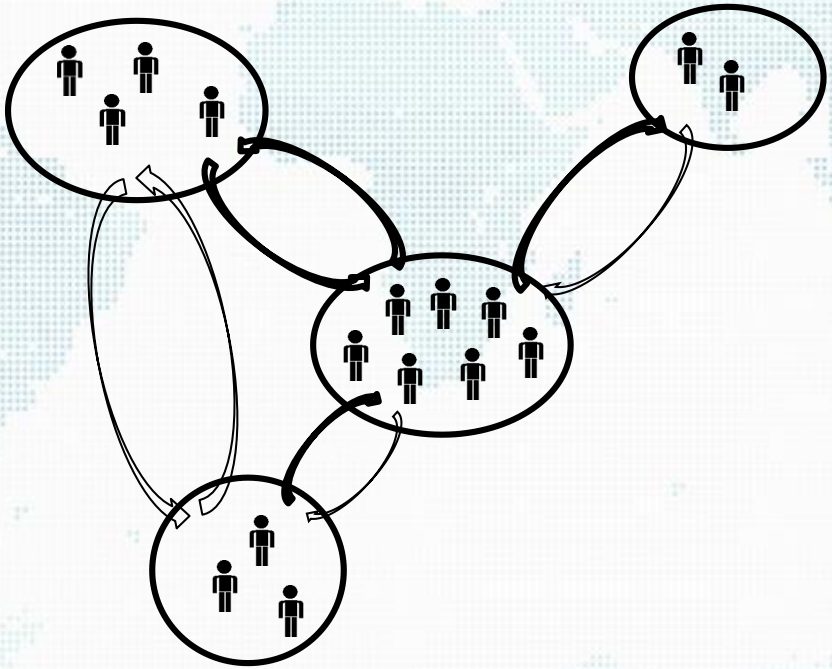






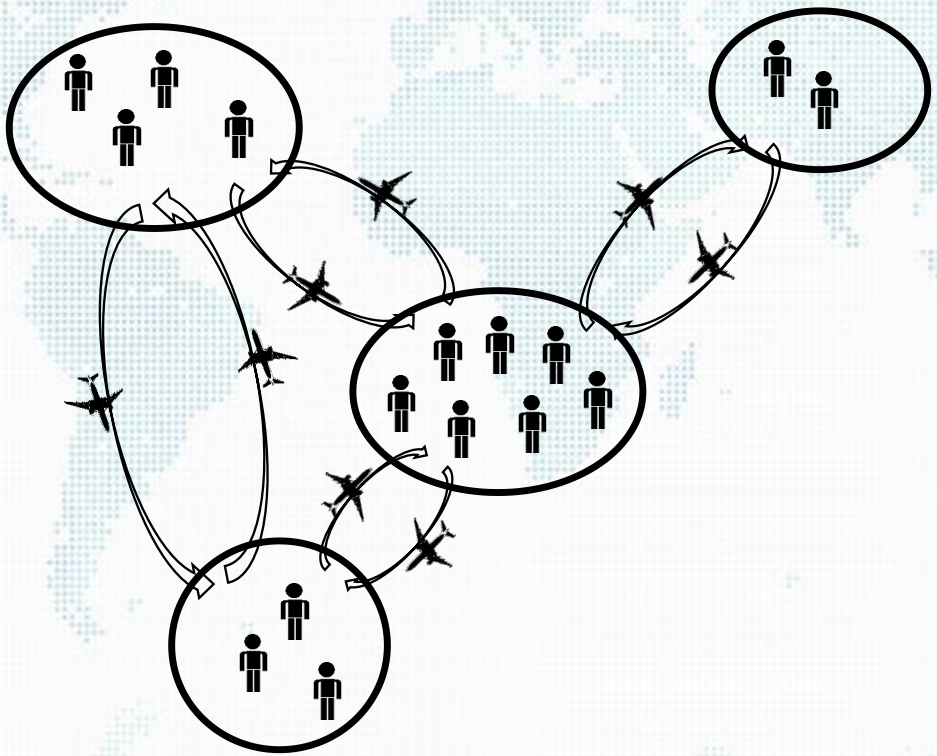
Metapopulation of superorganisms: cities

Metapopulation is a set of subpopulations not sufficiently isolated from each other to be independent, however, enough to keep distinct dynamics.

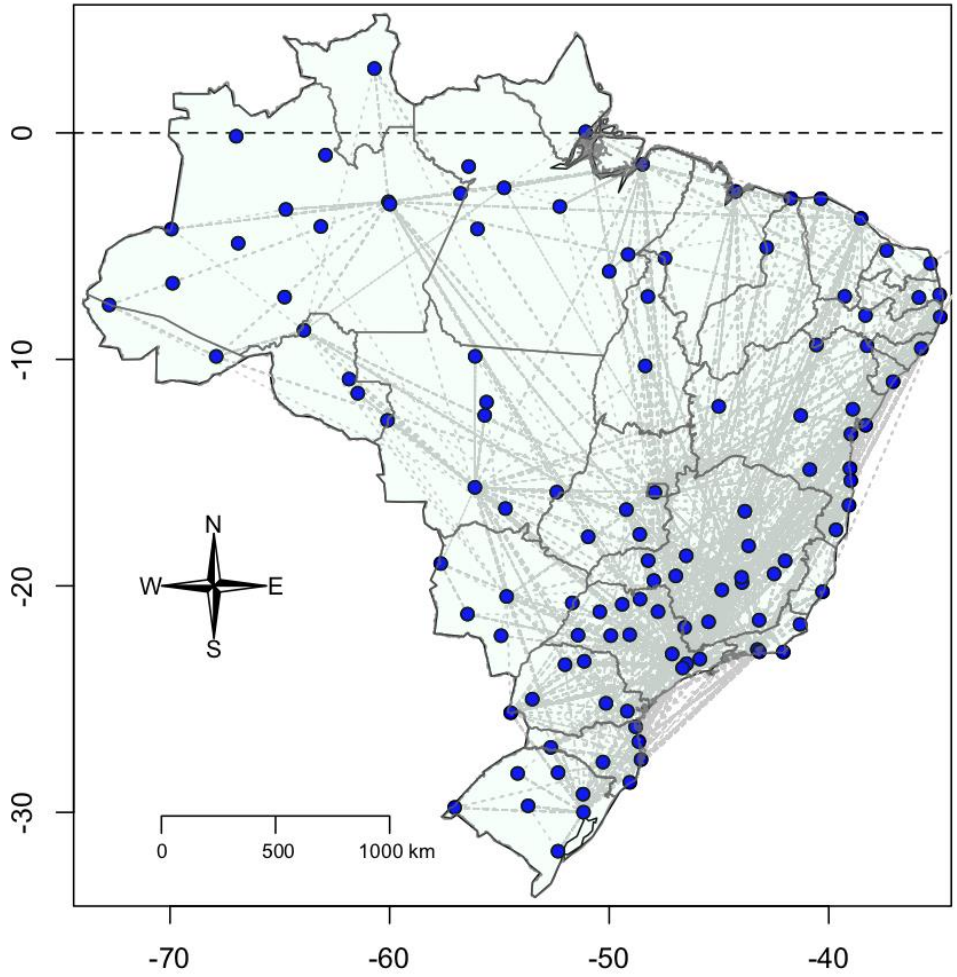


Flight network

Spreading of the disease among subpopulations happened under a graph topology defined by the regular city flights..



Brazilian Flight Network



1. **Second largest in the world, after US.**
2. **154 airports, 31 internationals.**
3. **Main arrivals: Guarulhos Brasília, Campinas.**
4. **Main departures: Guarulhos, Brasília, Belo Horizonte.**
5. **Main intermediation: Campinas, Belo Horizonte, Manaus.**
6. **All large airports with 100 % clustering.**

https://www.anac.gov.br/assuntos/dados-e-estatisticas/historico-de-voos

SIR Model

- Discrete version (one population):

1) $S_{t+1} = S_t - \frac{\beta}{N} S_t I_t$

2) $I_{t+1} = I_t + \frac{\beta}{N} S_t I_t - \gamma I_t$

3) $R_{t+1} = R_t + \gamma I_t$

→ N=S+I+R it the total population (constant)

→ $\frac{\beta}{N}$ is proportional to infection level

→ γ is the probability of recovery

- Metapopulation version

1) $$S_{t+1}^{i} = S_t^i - \frac{\beta}{N} S_t^i \left(I_t^i + \overline{I_t^i} \right)$$

2) $$I_{t+1}^{i} = I_t^i + \frac{\beta}{N} S_t^i \left(I_t^i + \overline{I_t^i} \right) - \gamma \left(I_t^i + \overline{I_t^i} \right)$$

3) $$R_{t+1}^{i} = R_t^i + \gamma \left(I_t^i + \overline{I_t^i} \right)$$

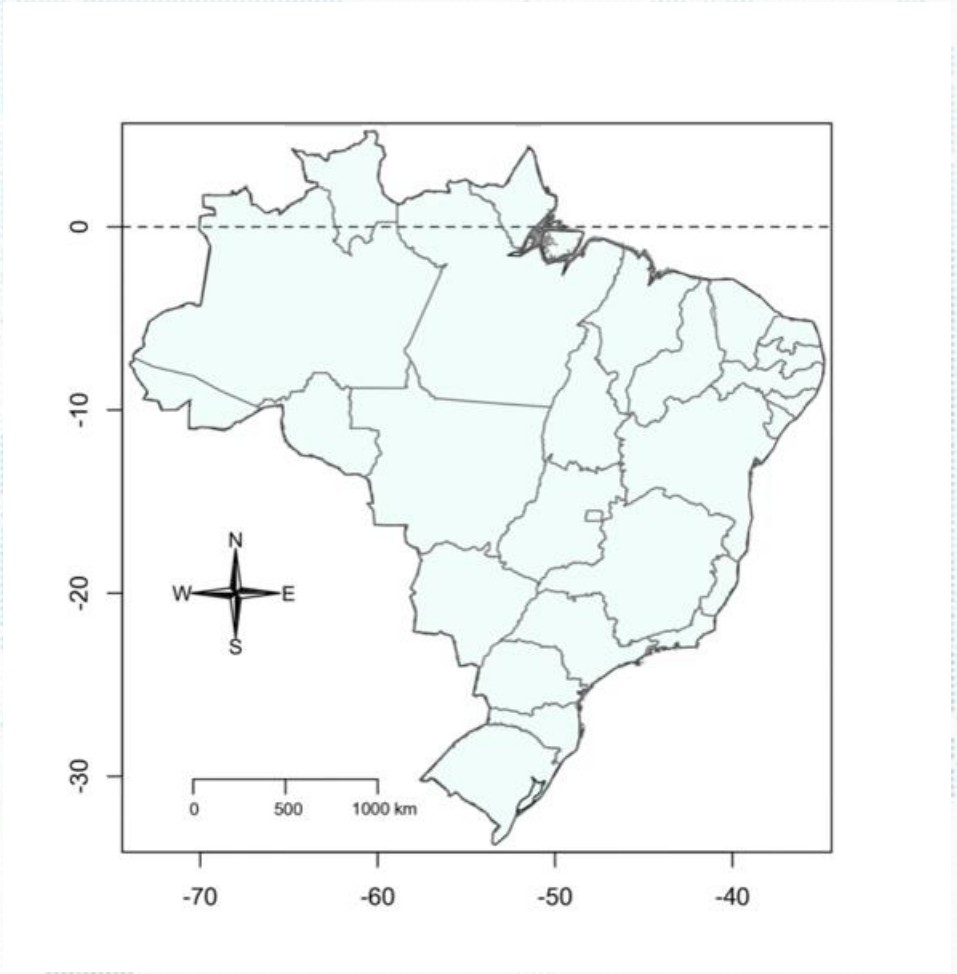
4) $$\overline{I_t^i} = \alpha \sum_{j=0}^{\mathrm{NA}} k_{i,j} I_j$$

$k_{i,j}$ = the number of flights departing at city *i* and arriving at city *j*

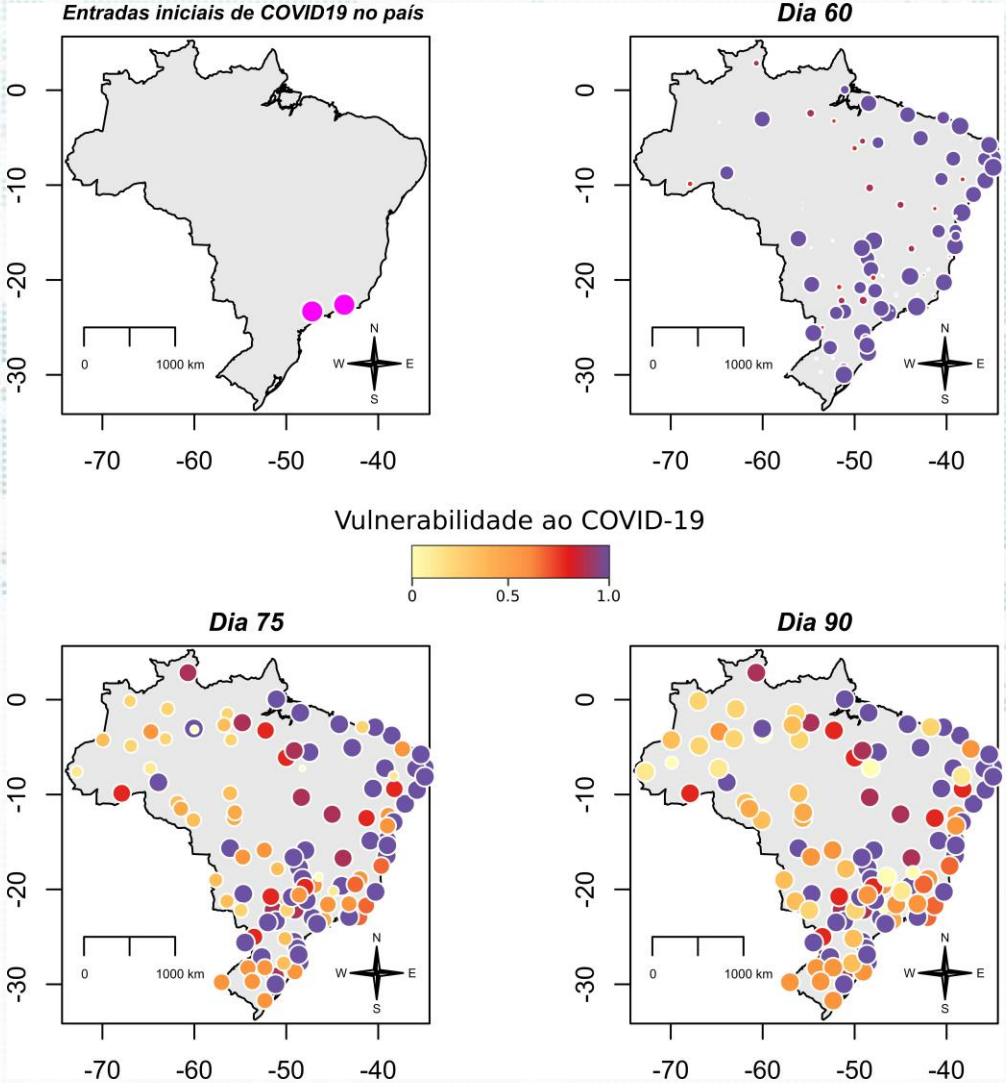
α =0.0001; //traveling infection parameter (modified SIR)

β =0.3035; //contact infection parameter

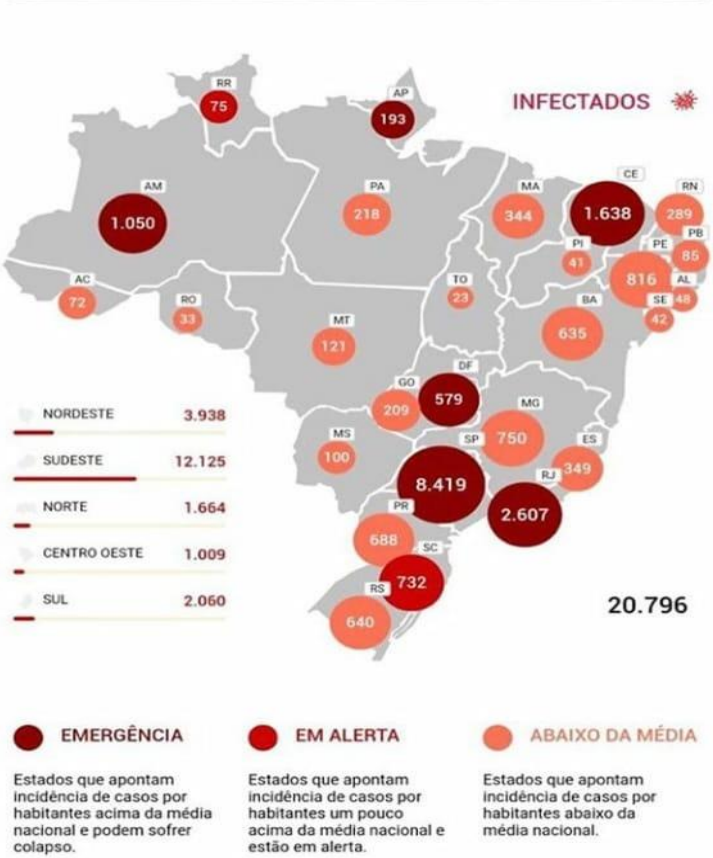
γ =0.0; //recovering parameter


0
-10
-20
-30
-70
-60
-50
-40
N
W
E
S
0
500
1000 km

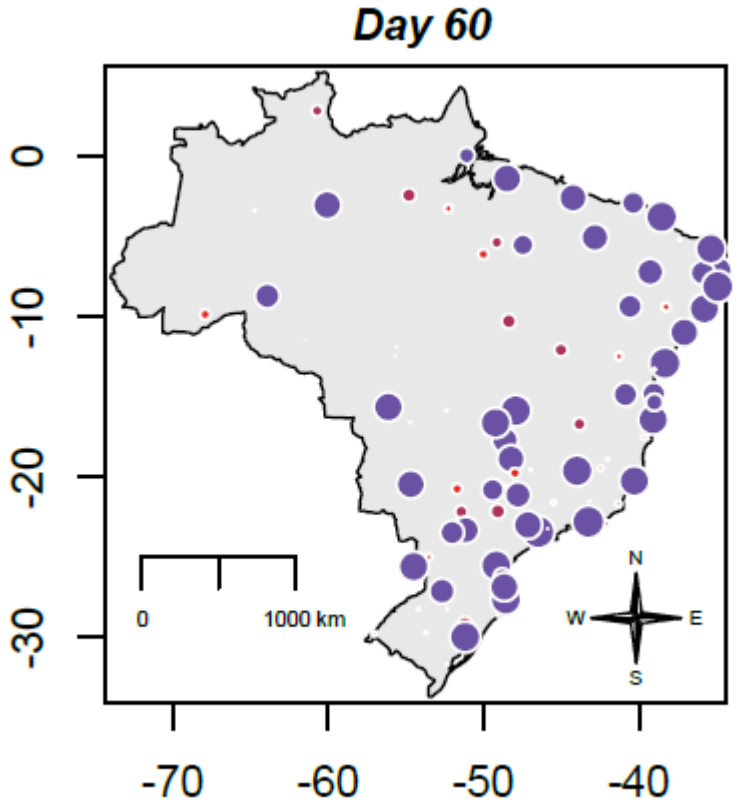
Results


Entradas iniciais de COVID19 no país
Dia 60
Vulnerabilidade ao COVID-19
0
0.5
1.0
Dia 75
Dia 90
0
-10
-20
-30
-70
-60
-50
-40
0
1000 km
N
W
E
S

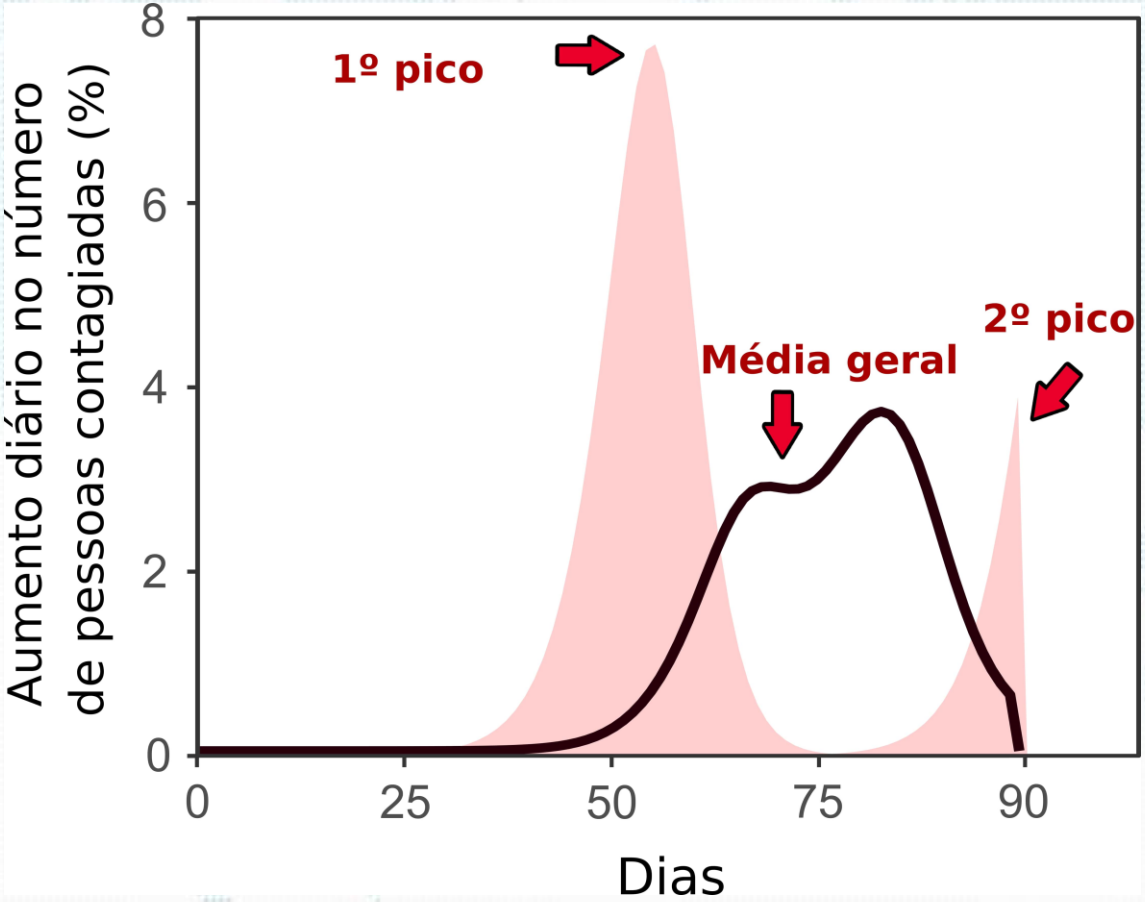
Real life
Day 45



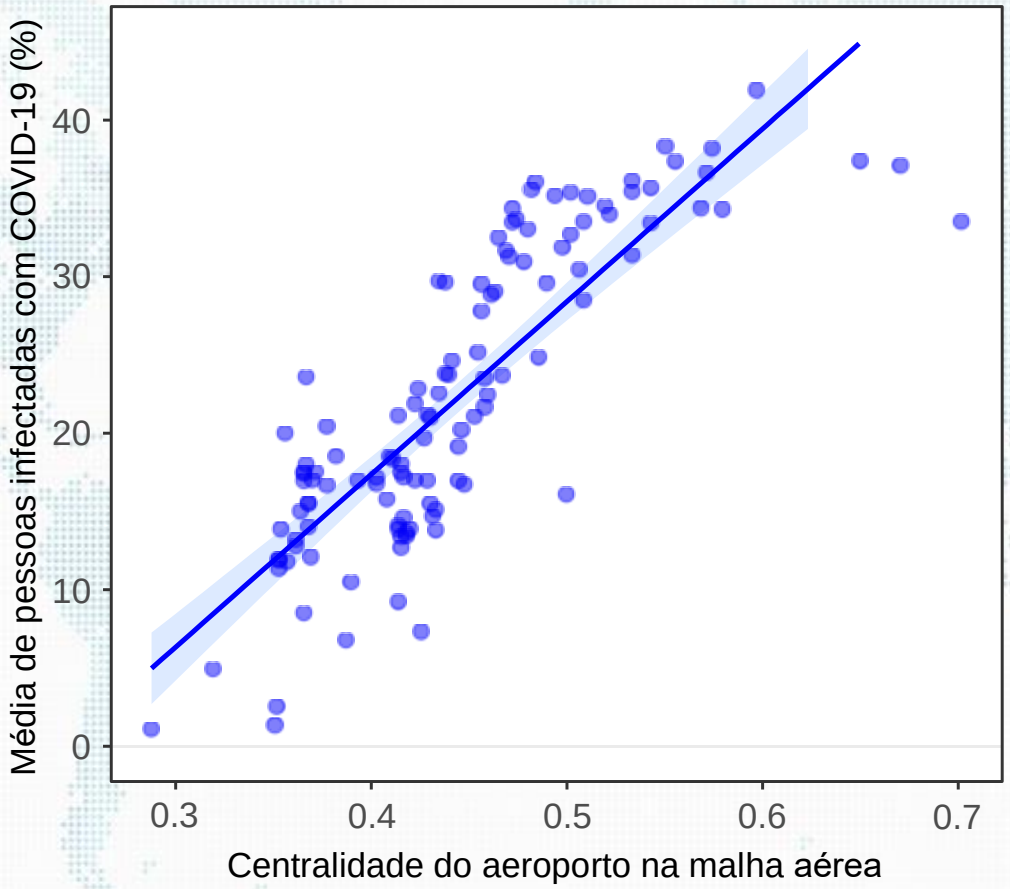
Model



Results


1º pico
Média geral
2º pico
Aumento diário no número de pessoas contagiadas (%)
0
2
4
6
8
0
25
50
75
90
Dias

Results


Média de pessoas infectadas com COVID-19 (%)
0
10
20
30
40
0.3
0.4
0.5
0.6
0.7
Centralidade do aeroporto na malha aérea

COVID-19 most vulnerable Mexican cities lack the health infrastructure to face the pandemic

Wesley Dáttilo[1,*] ; Alcides Castro e Silva[2] ; Roger Guevara[3] ; Ian MacGregor Fors[4] ; Sérvio Pontes Ribeiro[5]

Network Susceptible-Infected-Recovered model

Estimating overload in the intensive care units

Social distancing and the number of people infected

https://www.medrxiv.org/content/10.1101/2020.04.10.20061192v1.article-metrics

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Estimating overload in the intensive care units

Per city, we model how long time would take to overload the intensive care units:

$\Delta N=(I_1-I_2)\,\Delta t$, where

I_1 is the rate of incoming infected ones and
I_2 the rate of cured or died people leaving ICU.

The factor I_1 is calculated as a fraction of 5% of infected ones and assuming that one person stay 10 days in ICU (Wang et al. 2020)

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Social distancing and the number of people infected

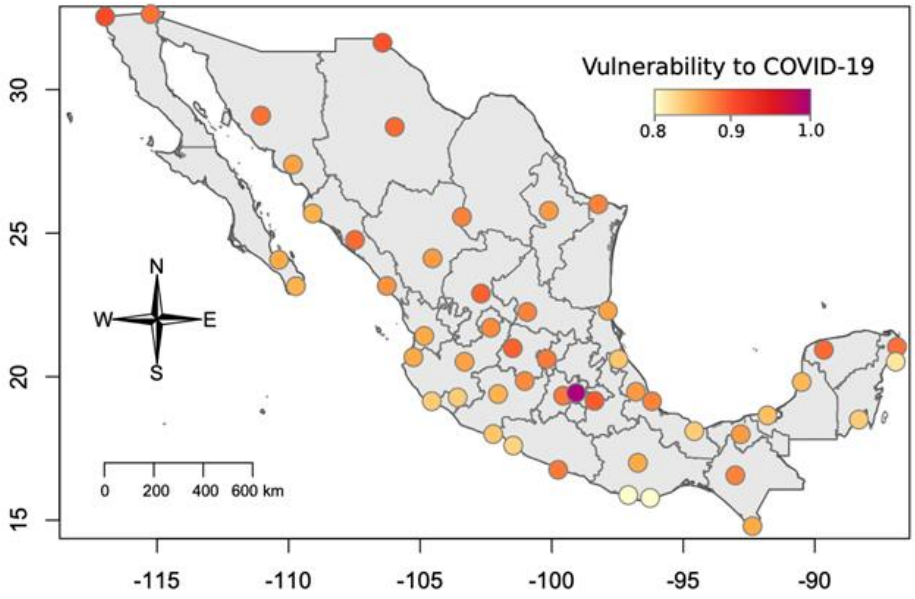
4 different social distance scenarios:

0%
15%
30%
45%

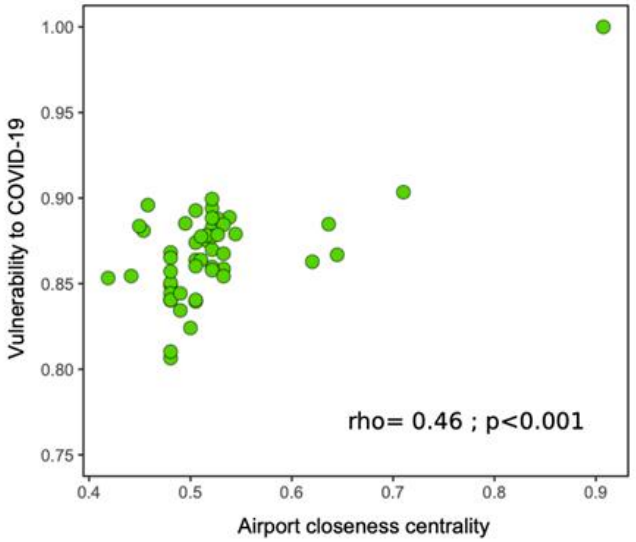
of isolation, based on the infection rate (β parameter)

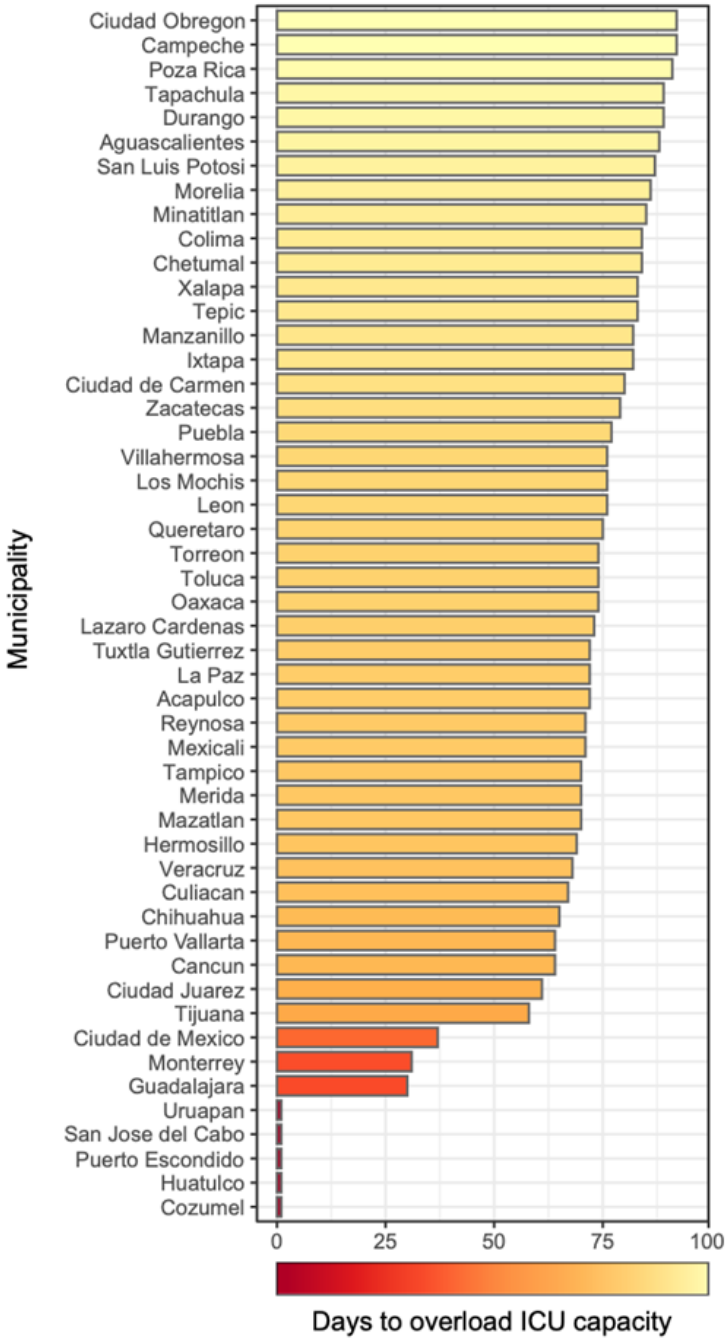
https://www.medrxiv.org/content/10.1101/2020.04.10.20061192v1.article-metrics

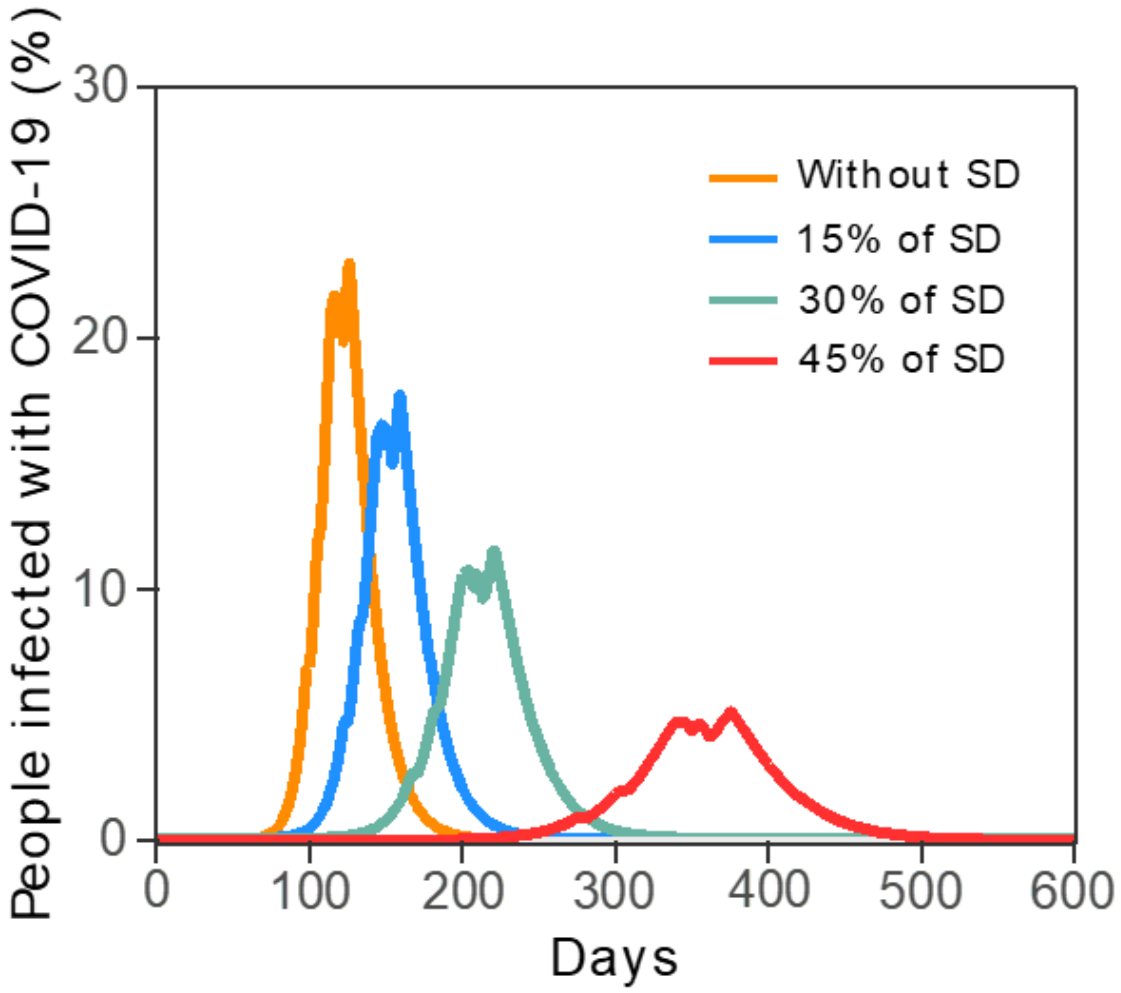
A)


Vulnerability to COVID-19
0.8
0.9
1.0
N
W
E
S
0
200
400
600 km
30
25
20
15
-115
-110
-105
-100
-95
-90

B)


Vulnerability to COVID-19
1.00
0.95
0.90
0.85
0.80
0.75
rho= 0.46 ; p<0.001
0.4
0.5
0.6
0.7
0.8
0.9
Airport closeness centrality


Municipality
Ciudad Obregon
Campeche
Poza Rica
Tapachula
Durango
Aguascalientes
San Luis Potosi
Morelia
Minatitlan
Colima
Chetumal
Xalapa
Tepic
Manzanillo
Ixtapa
Ciudad de Carmen
Zacatecas
Puebla
Villahermosa
Los Mochis
Leon
Queretaro
Torreon
Toluca
Oaxaca
Lazaro Cardenas
Tuxtla Gutierrez
La Paz
Acapulco
Reynosa
Mexicali
Tampico
Merida
Mazatlan
Hermosillo
Veracruz
Culiacan
Chihuahua
Puerto Vallarta
Cancun
Ciudad Juarez
Tijuana
Ciudad de Mexico
Monterrey
Guadalajara
Uruapan
San Jose del Cabo
Puerto Escondido
Huatulco
Cozumel
0
25
50
75
100
Days to overload ICU capacity


People infected with COVID-19 (%)
30
20
10
0
0
100
200
300
400
500
600
Days
Without SD
15% of SD
30% of SD
45% of SD

Conclusions

- ***Closeness defines airport vulnerability*.**
- **Dissemination peak of 50 days is among cities with large and key airports, and the peak of 90 days is the expected dissemination to the rest of the Country.**
- **Manaus is an airport highly clustered and with the strong intermediation, already under hospital saturation, even faster than our model predicted.**
- **Manaus will infect the rest of Amazon´s airport cities. We predicted a 20 days delay from Manaus to the least connected cities, such as Tabatinga.**
- **The "Risk Manaus" to the Amazon traditional and indigenous communities is even greater than we measured due to the strong river transport network centred in this city.**

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- *Closeness defines airport vulnerability*.
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Conclusions

- **Strong economic interests prevented worldwide the lockdown of airports, and now, the whole humanity is requested to isolate themselves in the cities-homes**

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