Data-Driven Modeling dan Forecasting untuk Transmisi COVID-19

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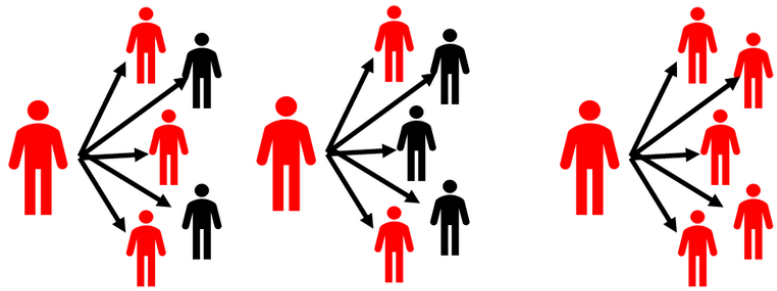
May 2020

Outline

- Tujuan
- Data yang tersedia
- Framework yang dipakai
  - Model dinamik
  - Vektor data
  - Asimilasi data
- Contact Index (CI)
- Hasil dan pembahasan

Tujuan

- Mengukur intensitas penyebaran COVID-19



- Proyeksi satu bulan kedepan (forecasting)

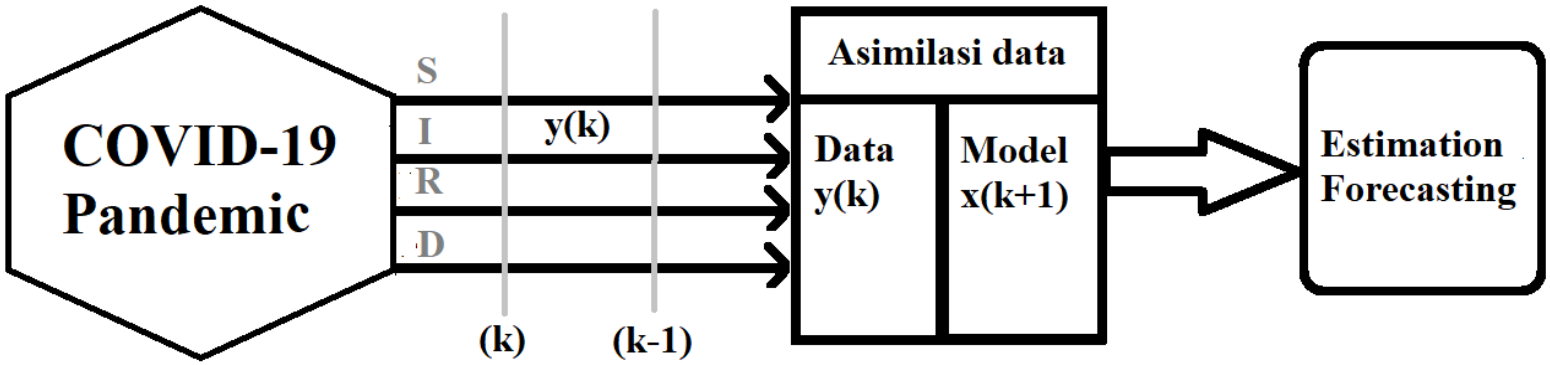
Data yang tersedia

Jumlah populasi: N = 273523615

Date	Month	Susceptible (S)	Infectious (I)	Recovered (R)	Dead (D)
⋮	⋮	⋮	⋮	⋮	⋮
28	4	273512077	7484	1254	773
29	4	273511669	7596	1391	784
30	4	273511183	7804	1522	792
1	5	273510673	8160	1591	800
2	5	273510276	8347	1665	831
3	5	273509702	8471	1876	845
⋮	⋮	⋮	⋮	⋮	⋮

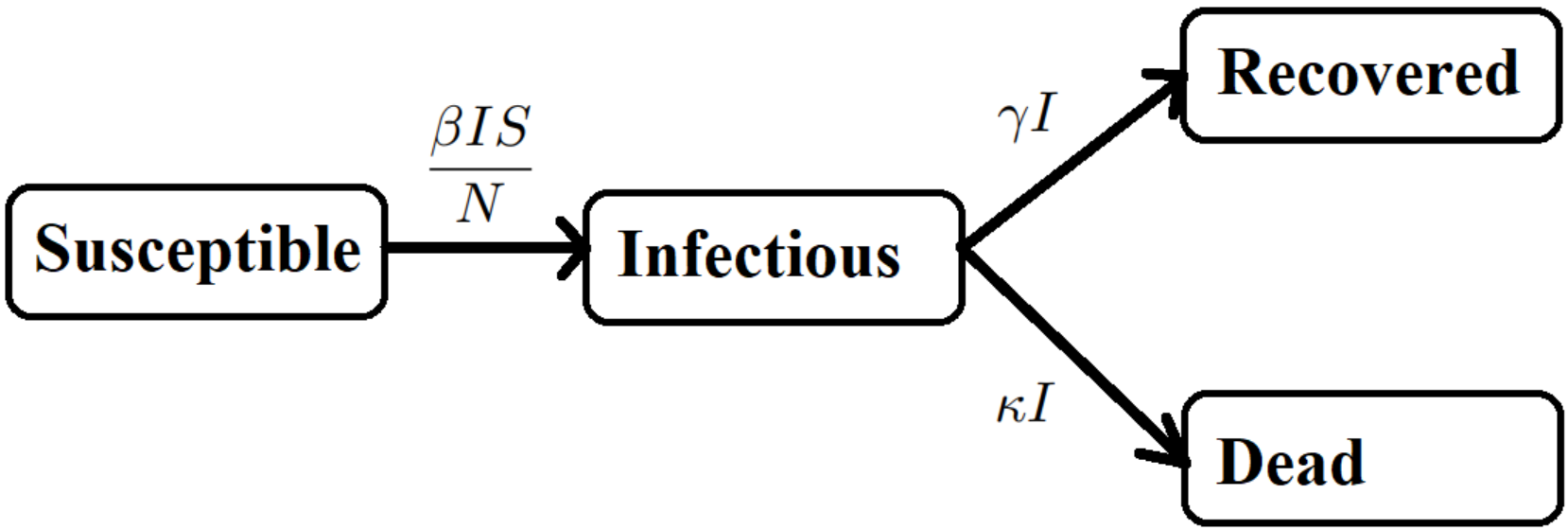
- `https://www.worldometers.info/coronavirus/`
- `https://kawalcovid19.id/`
- `https://corona.jakarta.go.id/id/data-pemantauan`
- `etc`

Framework yang dipakai



- Model dinamik ($\boldsymbol{x}(k+1)$)
- Vektor data ($\boldsymbol{y}(k)$)
- Asimilasi data

Model dinamik



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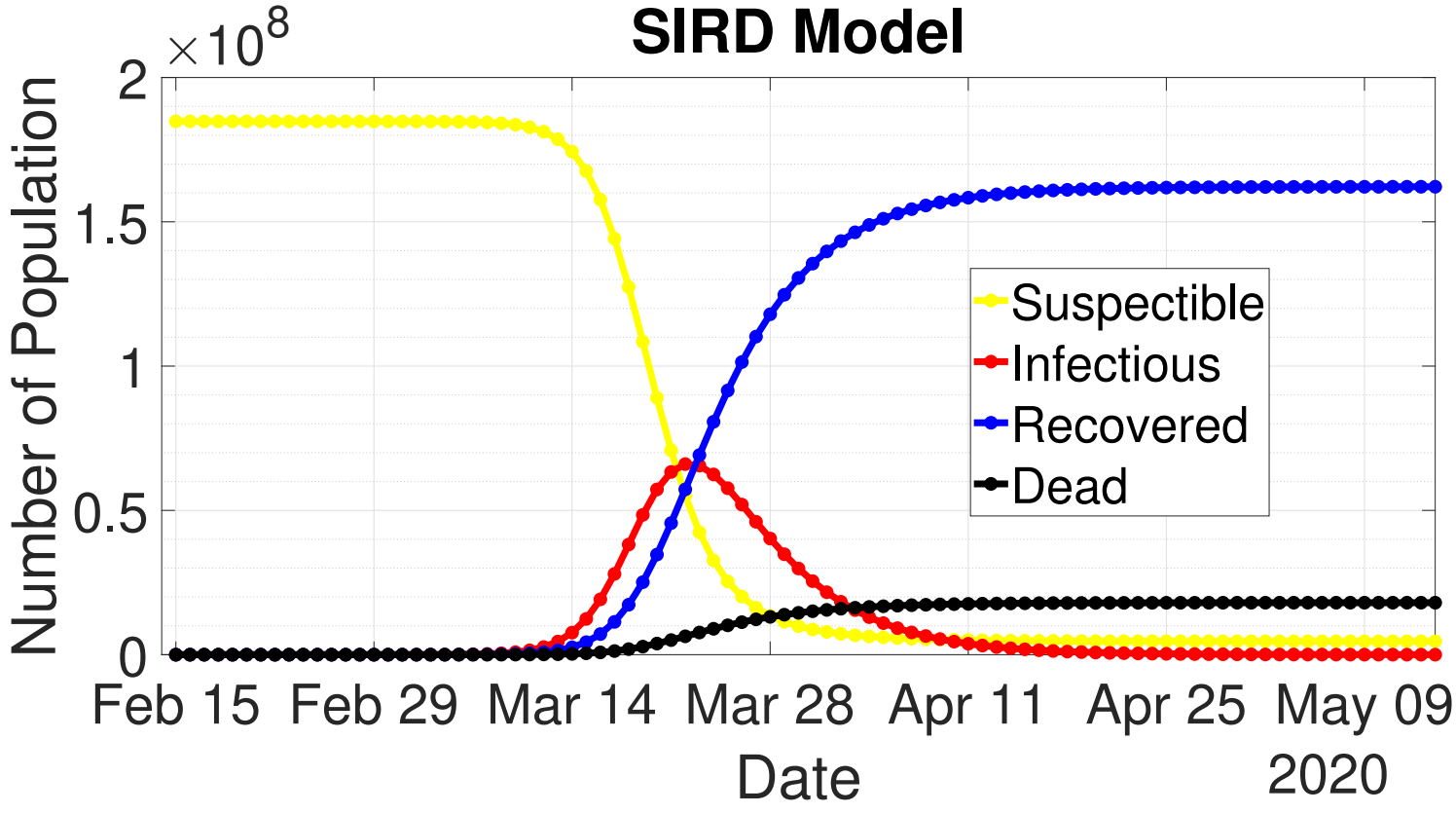
Model dinamik



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Model dinamik

Discrete-time stochastic augmented compartmental model.

$$
\begin{aligned}
S(k+1) &= \left(1 - \frac{\Delta t}{NT_i} R_t(k) I(k)\right) S(k) \\
I(k+1) &= (1 - \frac{\Delta t}{T_i}) I(k) + \frac{\Delta t}{NT_i} R_t(k) I(k) S(k) \\
R(k+1) &= R(k) + \frac{1-\chi}{T_i} \Delta t I(k) \\
D(k+1) &= D(k) + \frac{\chi}{T_i} \Delta t I(k) \\
R_t(k+1) &= R_t(k)
\end{aligned}
$$

parameter	simbol
Case-Fatality Rate	χ
waktu infeksi	T_i

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Model dinamik

Discrete-time stochastic augmented compartmental model.

$$
\begin{aligned}
S(k+1) &= \left(1 - \frac{\Delta t}{NT_i} R_t(k) I(k)\right) S(k) + w_1 \\
I(k+1) &= (1 - \frac{\Delta t}{T_i}) I(k) + \frac{\Delta t}{NT_i} R_t(k) I(k) S(k) + w_2 \\
R(k+1) &= R(k) + \frac{1-\chi}{T_i} \Delta t I(k) + w_3 \\
D(k+1) &= D(k) + \frac{\chi}{T_i} \Delta t I(k) + w_4 \\
R_t(k+1) &= R_t(k) + w_5
\end{aligned}
$$

parameter	simbol
Case-Fatality Rate	χ
waktu infeksi	T_i

Model dinamik

Discrete-time stochastic augmented compartmental model.

$$
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R_t(k+1) &= R_t(k) + w_5
\end{aligned}
$$

parameter	simbol
Case-Fatality Rate	χ
waktu infeksi	T_i

$\boldsymbol{w}(k) \sim \mathcal{N}(0, \boldsymbol{Q})$ ← distribusi normal.

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Model dinamik

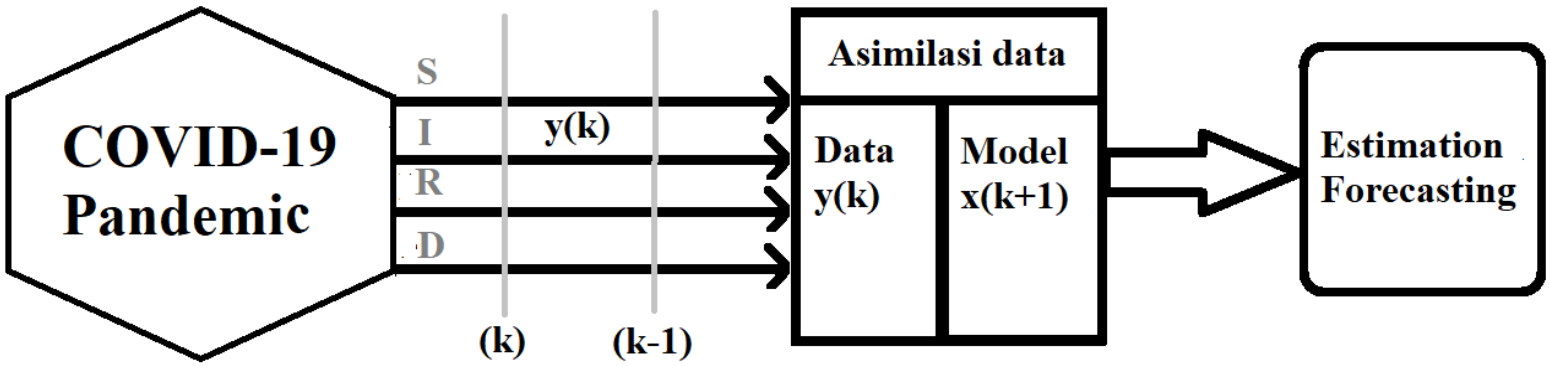
Kita definisikan

$$\boldsymbol{x}(k+1) \quad = \quad \begin{pmatrix} S(k+1) \\ I(k+1) \\ R(k+1) \\ D(k+1) \\ R_t(k+1) \end{pmatrix}$$

Model diskrit dapat ditulis sebagai

$$\boldsymbol{x}(k+1) \quad = \quad \boldsymbol{f}(\boldsymbol{x}(k)) + \boldsymbol{w}(k)$$

Framework yang dipakai



- Model dinamik ($\boldsymbol{x}(k+1)$)✓
- Vektor data ($\boldsymbol{y}(k)$)
- Asimilasi data

Vektor Data

Vektor data dapat ditulis sebagai

$$\boldsymbol{y}(k) = \begin{pmatrix} S(k) \\ I(k) \\ R(k) \\ D(k) \end{pmatrix}$$

Vektor Data

Vektor data dapat ditulis sebagai

$$\boldsymbol{y}(k) = \begin{pmatrix} S(k) \\ I(k) \\ R(k) \\ D(k) \end{pmatrix} = \underbrace{\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{pmatrix}}_{\boldsymbol{C}} \underbrace{\begin{pmatrix} S(k) \\ I(k) \\ R(k) \\ D(k) \\ R_t(k) \end{pmatrix}}_{\boldsymbol{x}(k)}$$

Vektor Data

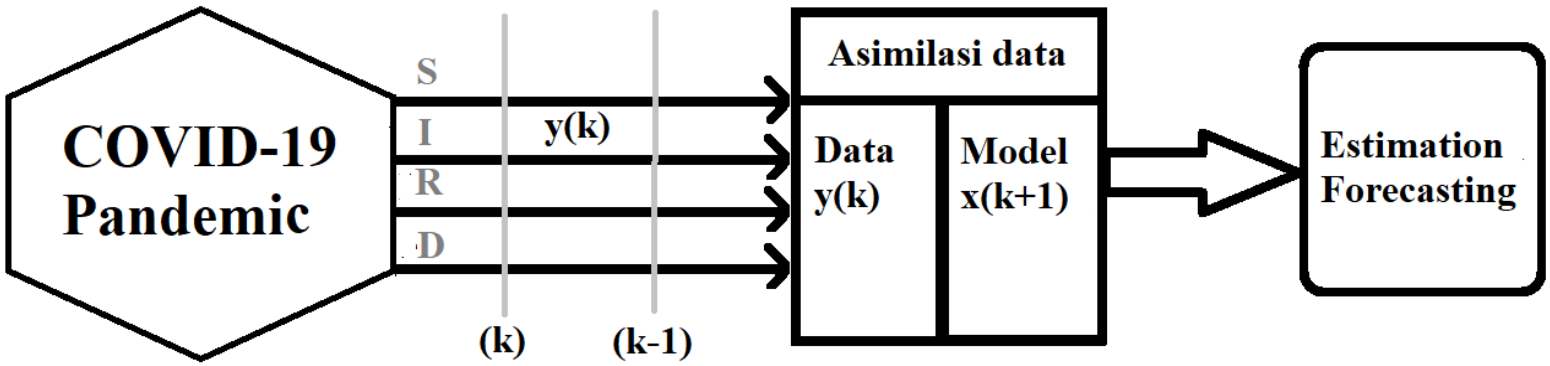
Vektor data dapat ditulis sebagai

$$\boldsymbol{y}(k) = \begin{pmatrix} S(k) \\ I(k) \\ R(k) \\ D(k) \end{pmatrix} = \underbrace{\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{pmatrix}}_{\boldsymbol{C}} \underbrace{\begin{pmatrix} S(k) \\ I(k) \\ R(k) \\ D(k) \\ R_t(k) \end{pmatrix}}_{\boldsymbol{x}(k)} + \boldsymbol{v}(k)$$

Asumsi

$\boldsymbol{v}(k) \sim \mathcal{N}(0, \boldsymbol{R})$ $\leftarrow$ distribusi normal.

Framework yang dipakai



- Model dinamik $(\boldsymbol{x}(k+1))\checkmark$
- Vektor data $(\boldsymbol{y}(k))\checkmark$
- Asimilasi data

Asimilasi Data

Inisialisasi $\boldsymbol{Q}$, $\boldsymbol{R}$, $\boldsymbol{P}(0|0)$

Prediksi

$$\hat{\boldsymbol{x}}(k|k-1) = \boldsymbol{f}(\hat{\boldsymbol{x}}(k-1|k-1))$$

$$\boldsymbol{P}(k|k-1) = \boldsymbol{F}(k)\boldsymbol{P}(k|k-1)\boldsymbol{F}(k)^{\mathsf{T}} + \boldsymbol{Q}$$

Update

$$\boldsymbol{K}(k) = \boldsymbol{P}(k|k-1)\boldsymbol{C}^{\mathsf{T}}\left(\boldsymbol{C}\boldsymbol{P}(k|k-1)\boldsymbol{C}^{\mathsf{T}} + \boldsymbol{R}\right)^{-1}$$

$$\underbrace{\hat{\boldsymbol{x}}(k|k)}_{\text{posteriori estimate}} = \underbrace{\hat{\boldsymbol{x}}(k|k-1)}_{\text{priori estimate}} + \underbrace{\boldsymbol{K}(k)}_{\text{Kalman gain}} \underbrace{\left(\boldsymbol{y}(k) - \boldsymbol{C}\hat{\boldsymbol{x}}(k|k-1)\right)}_{\text{data injeksi}}$$

$$\boldsymbol{P}(k|k) = (\boldsymbol{I} - \boldsymbol{K}(k)\boldsymbol{C})\boldsymbol{P}(k|k-1)$$

$\boldsymbol{F}(k)$ adalah matrix Jacobi dari $\boldsymbol{f}(k)$.

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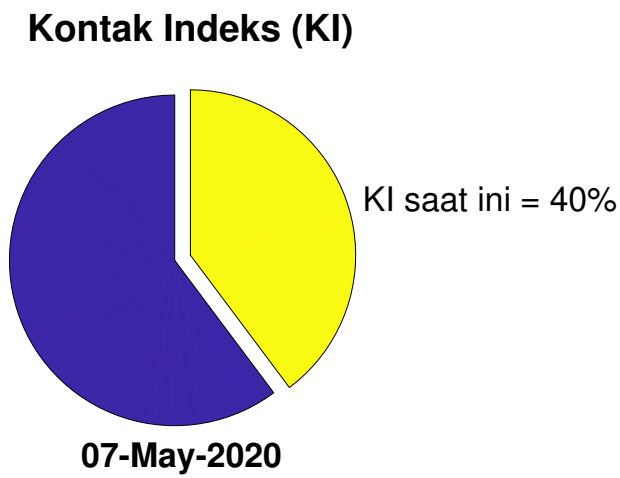
Contact Index (CI)

$$\text{CI} = \frac{R_t}{R_0} \text{ atau } \text{CI} = \frac{R_t}{Rt_{max}}$$



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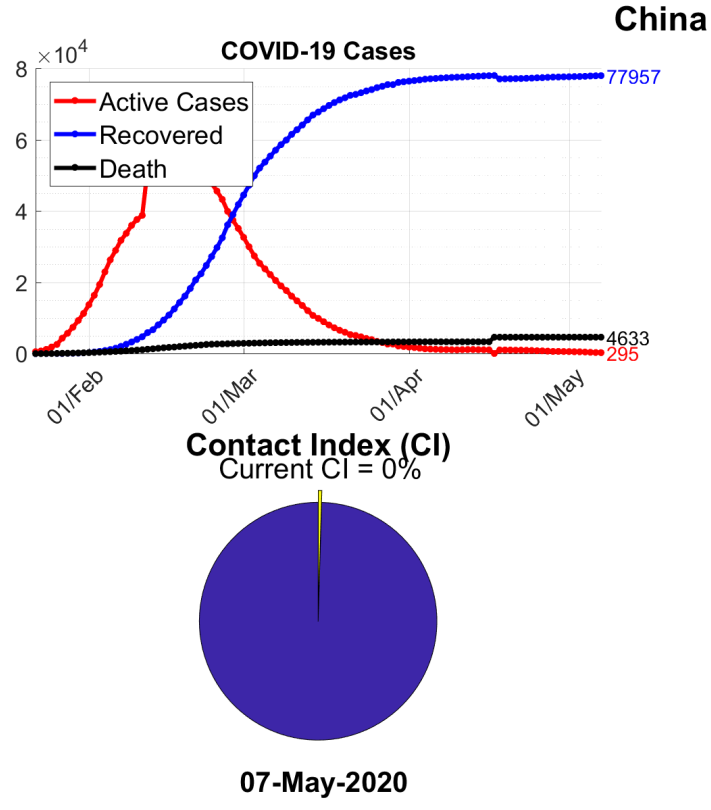
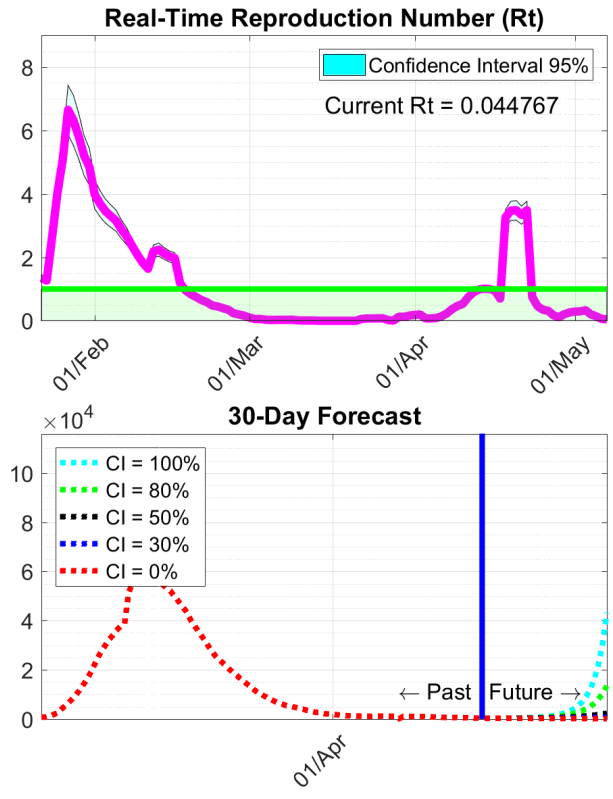
Total lockdown





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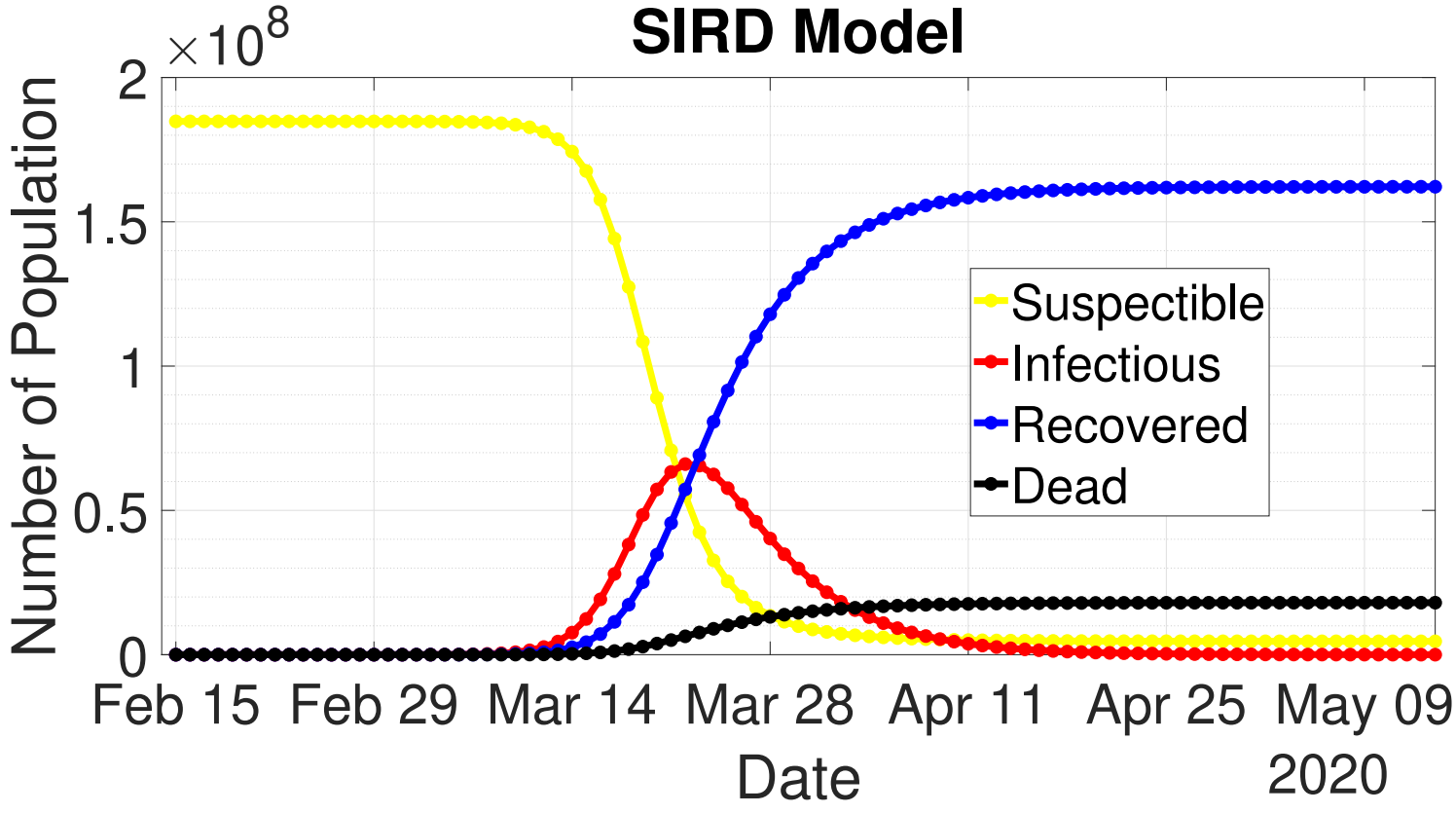
Model dinamik



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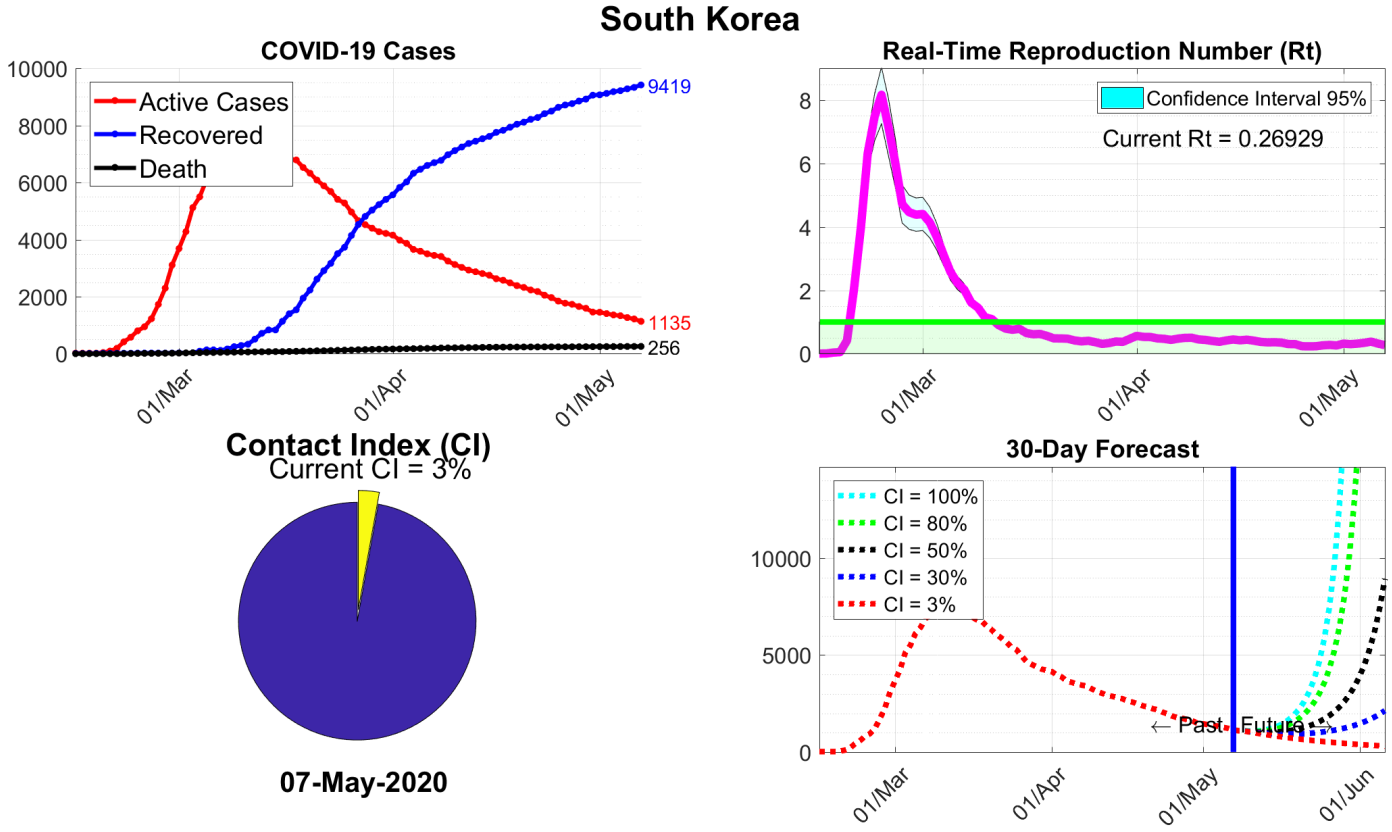
Testing, Tracing, Tracking, Treating



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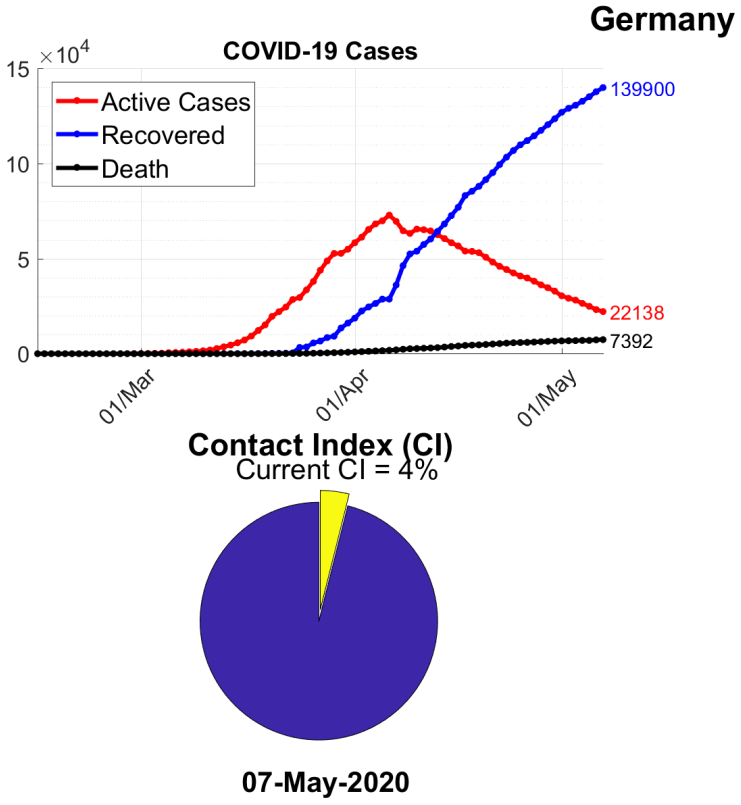
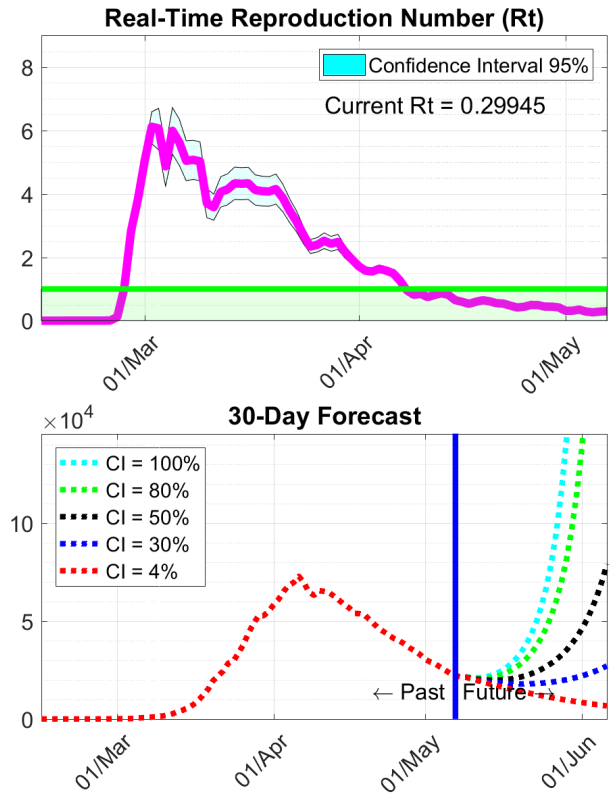
Lockdown





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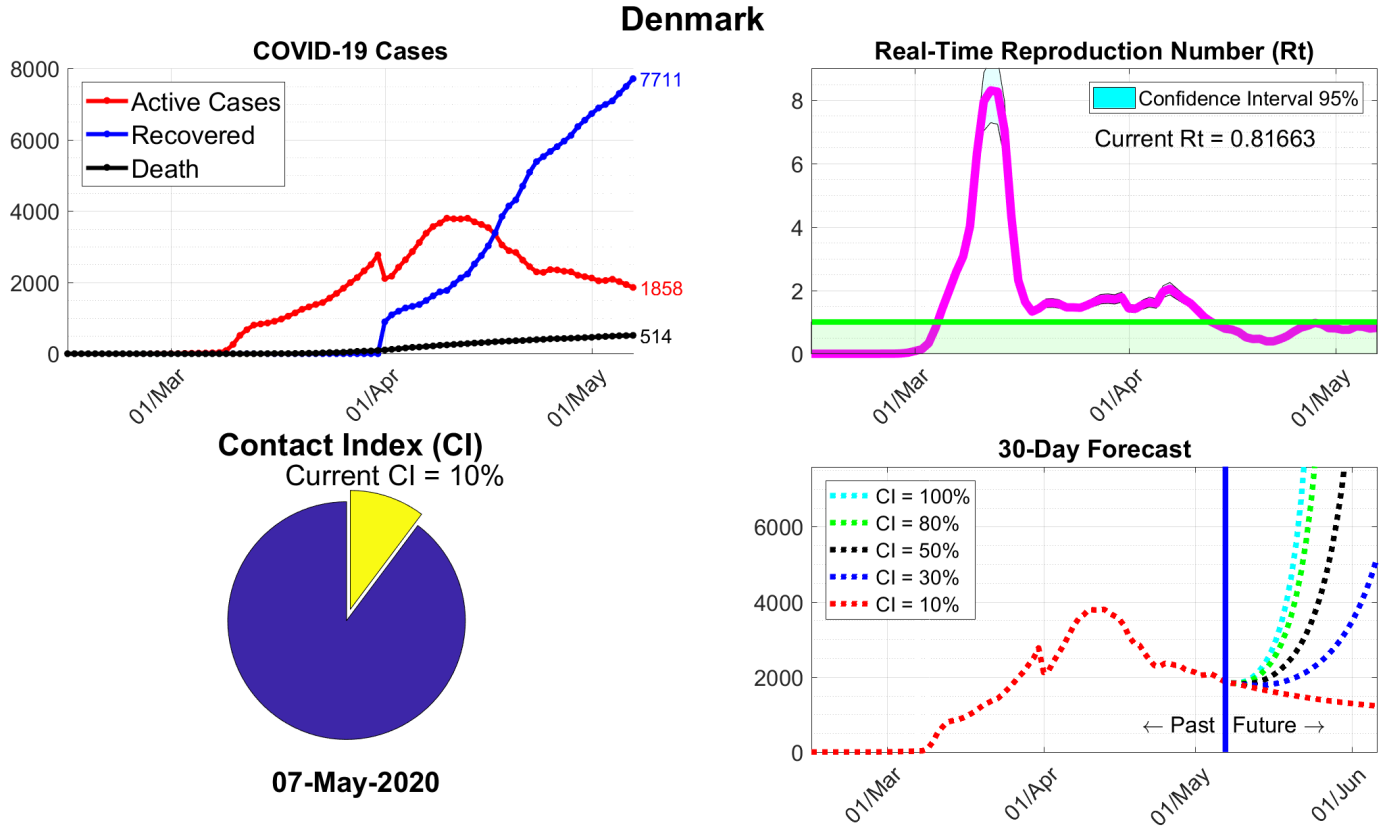
Lockdown



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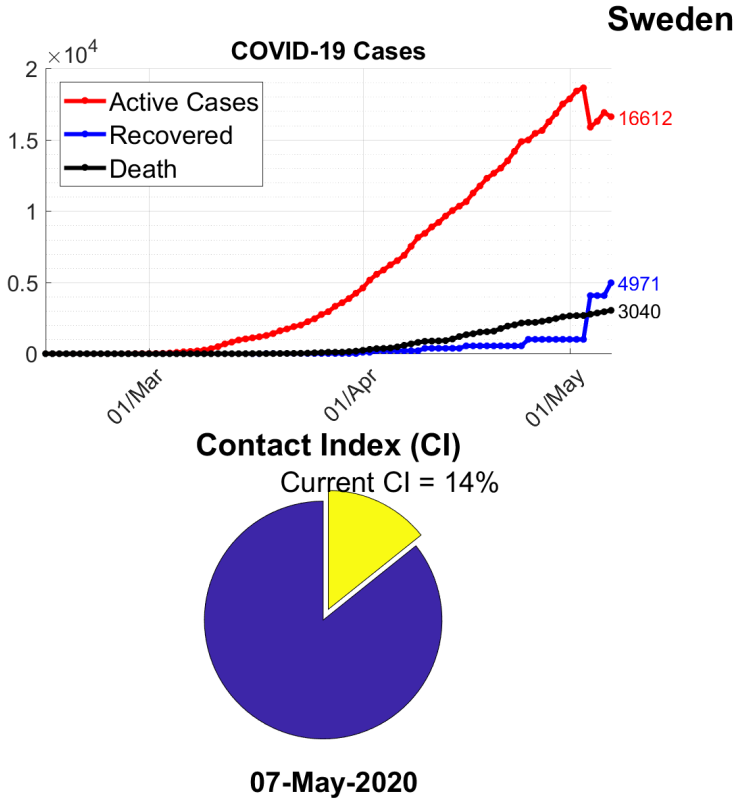
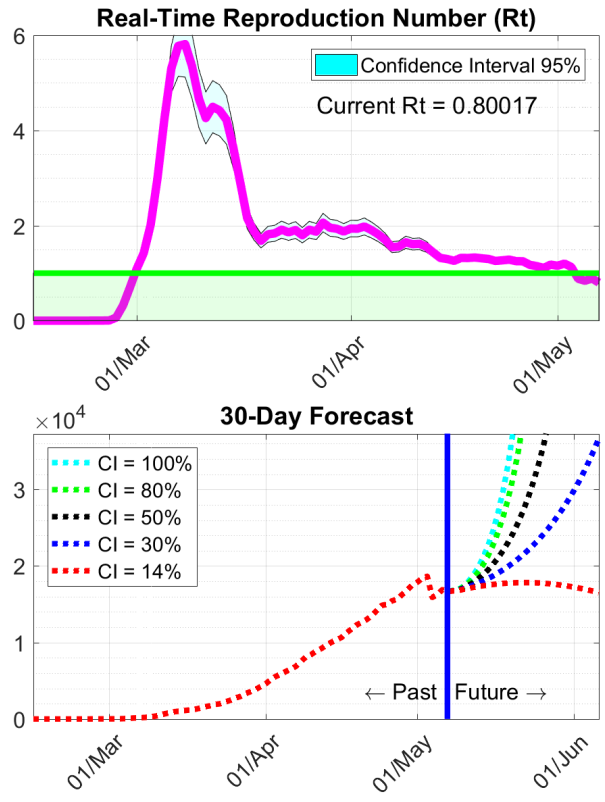
Physical distancing





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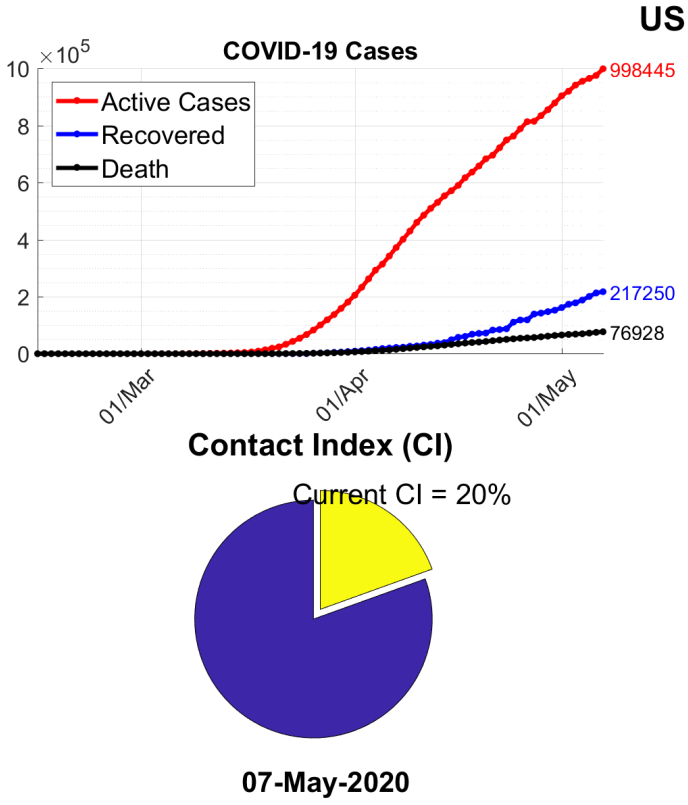

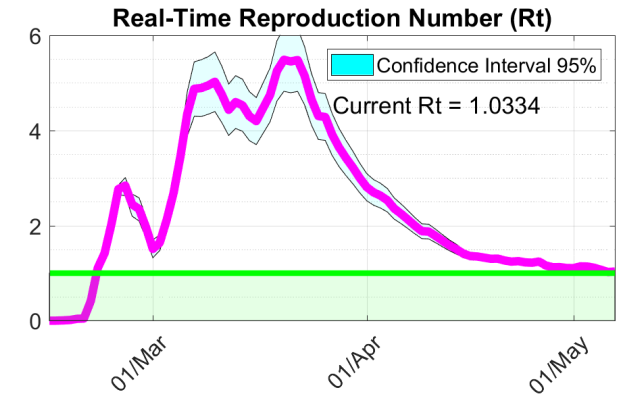

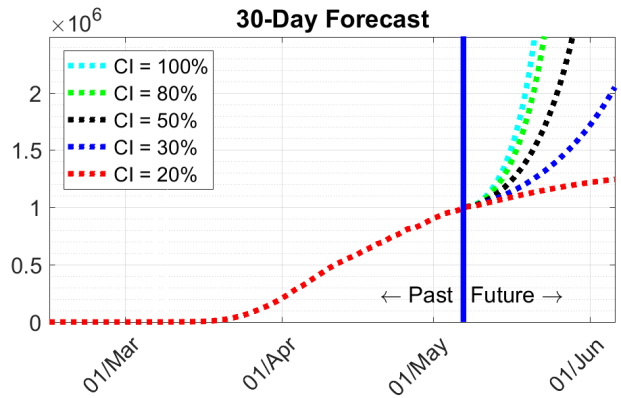

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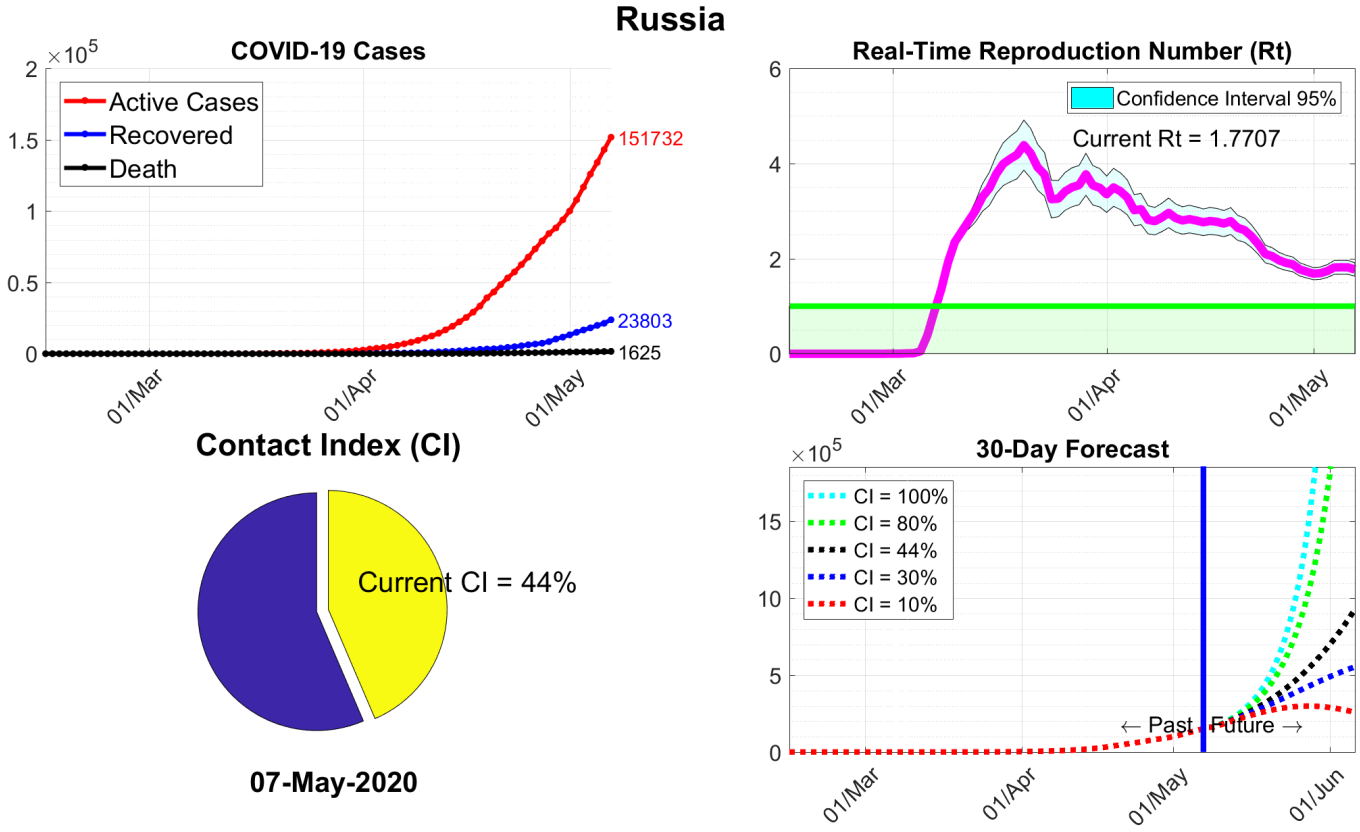
Lockdown



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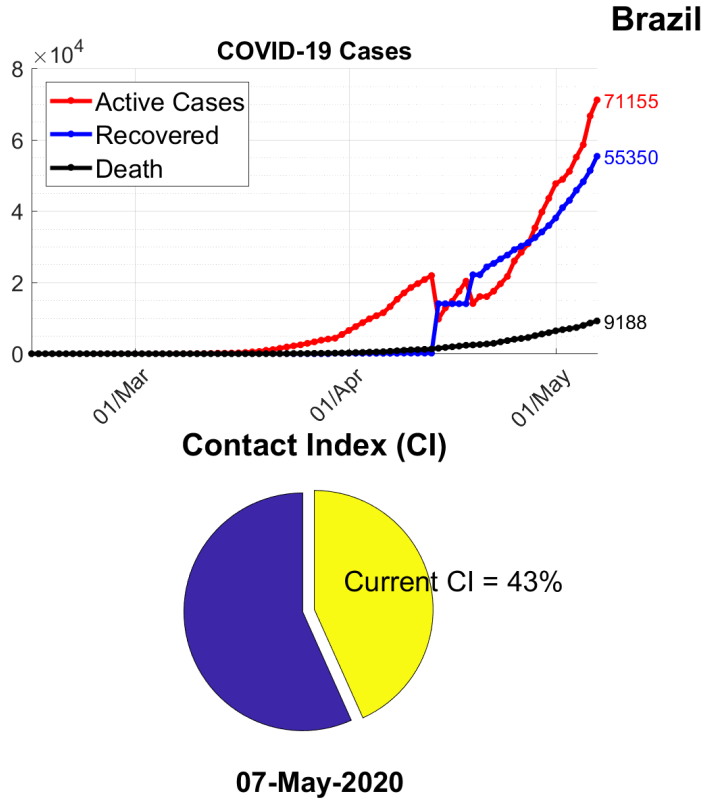
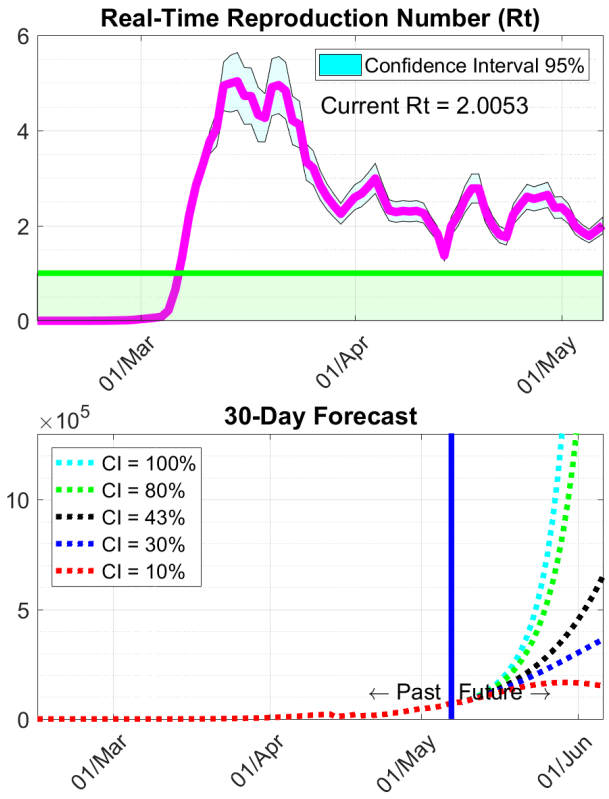
Partial lockdown





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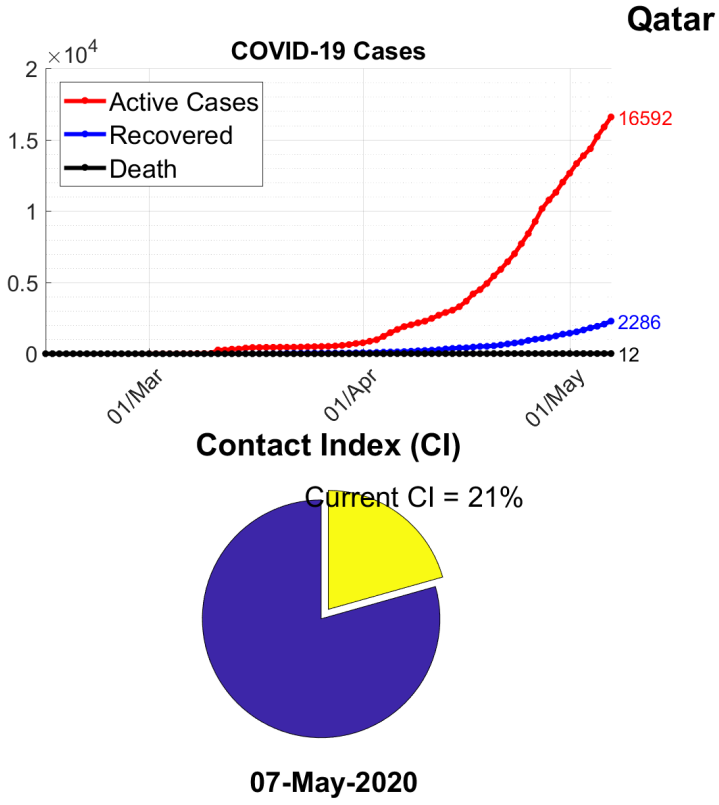

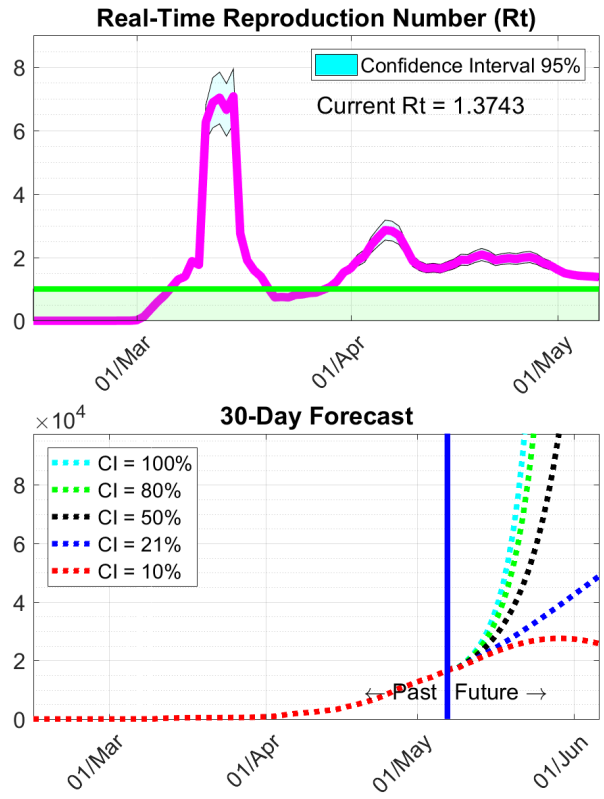

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