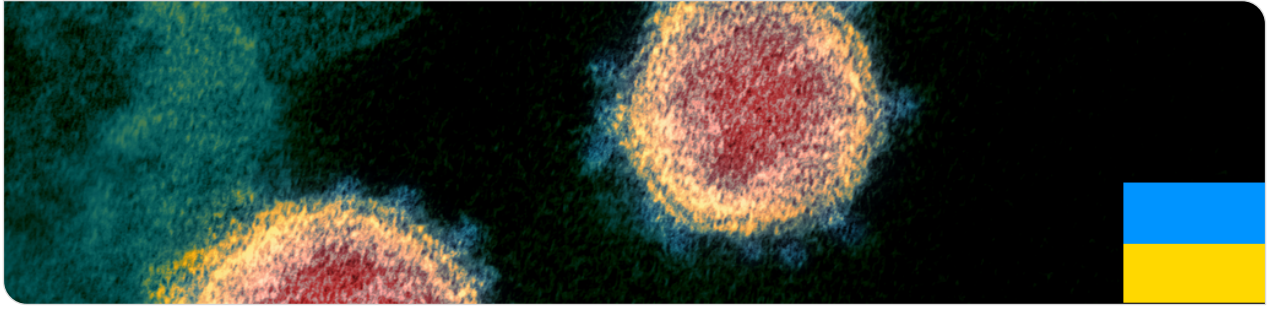
Karlsruher Institut für Technologie

Collaborative nowcasting of COVID-19 hospitalization incidences

DAGStat

Johannes Bracher | Karlsruhe Institute of Technology / Heidelberg Institute for Theoretical Studies



Contributors

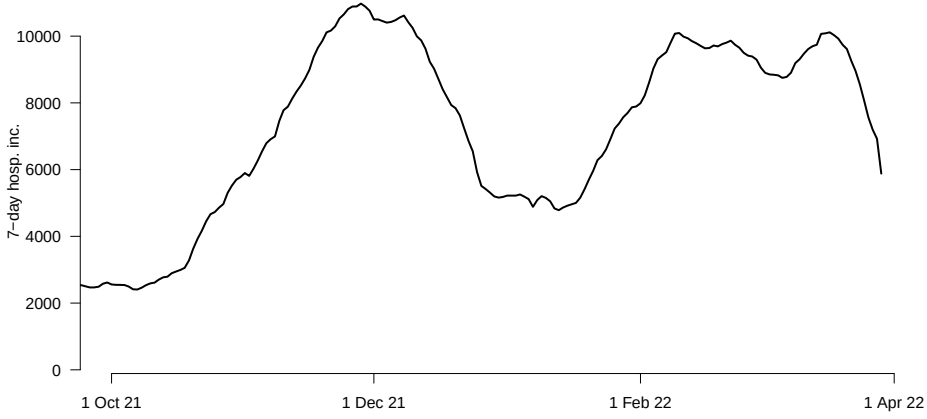
This is joint work with

- Daniel Wolffram, Davide Hailer, Tilmann Gneiting, Melanie Schienle (KIT/HITS)
- Helmut Küchenhoff, Diella Syliqi, Maximilan Weigert (LMU Munich)
- Sam Abbott, Sebastian Funk (London School of Hygiene and Tropical Medicine)
- Jan van de Kassteele (RIVM Bilthoven)
- Matthias an der Heiden, Alexander Ullrich (Robert Koch Institut)
- Stefan Heyder, Thomas Hotz (TU Ilmenau)
- Felix Günther (University of Stockholm)

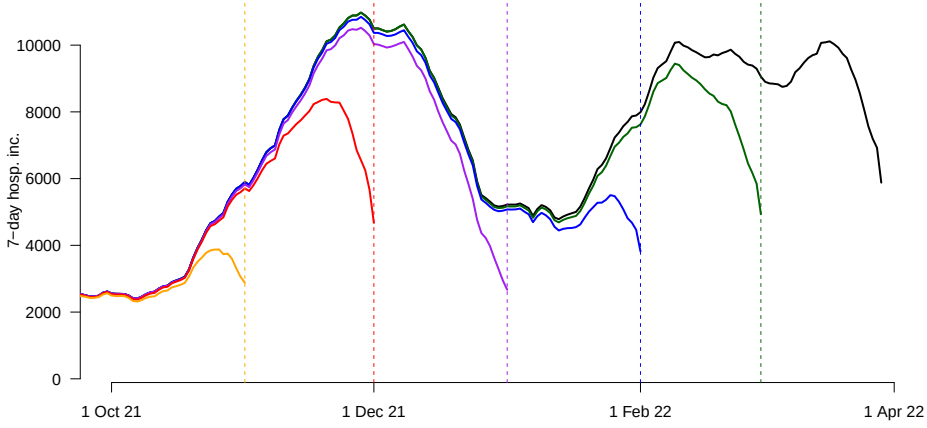
with contributions by

- Sören Müller-Hansen (Süddeutsche Zeitung)

COVID-19 hospitalization incidence in Germany



COVID-19 hospitalization incidence in Germany

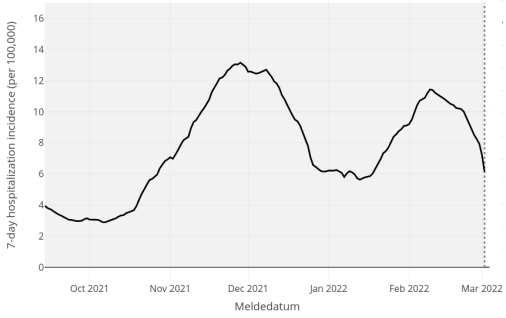


Seven day hospitalization incidence

- **Definition:** The number of persons, who over a seven-day period
  - have been registered electronically as a COVID-19 case by a local health authority (*Meldedatum*).
  - and have been hospitalized (not necessarily during the seven-day period).
- This is *not* the number of new hospitalizations over the last seven days.
- This number does *not* take into account whether COVID-19 was the reason of hospitalization.
- Advantage: “aligns” case and hospitalization numbers, thus useful for many (retrospective) analyses.
- Disadvantage: **Most recent values are biased downwards due to two types of delays:**
  - delay between *Meldedatum* ($\approx$ positive test) and hospitalization.
  - delay between hospitalization and appearance in RKI data.

Nowcasting aims to correct the reporting dip

- Goal: **Estimate (predict) what preliminary/incomplete values will ultimately look like.**
- Stratified analyses for states and age groups.
- Actually more of a forecast: not all hospitalizations in question have already happened
  - E.g., RKI usually uses the term “corrected hospitalization incidence” instead of “nowcast”



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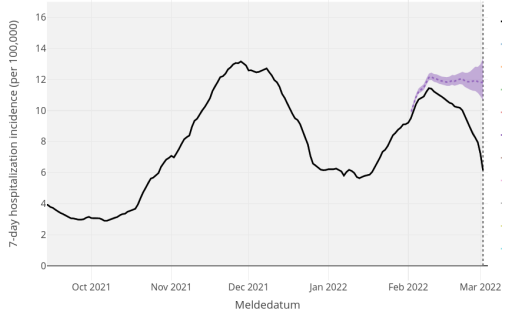
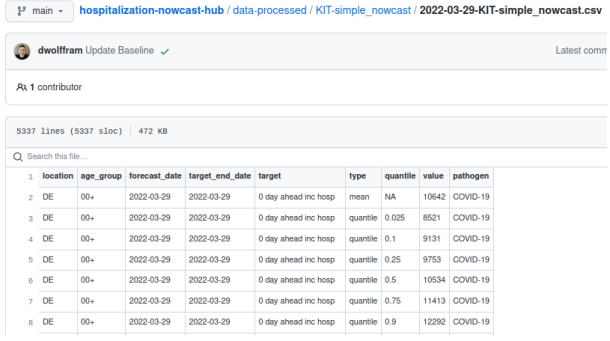


Multi-model nowcasting

- Experience from e.g., weather forecasting shows that combining different models can improve predictions
- We collect and combine probabilistic nowcasts from 8 independently run models.
- Daily subimssions to a public GitHub repository:



main ▾ **hospitalization-nowcast-hub** / data-processed / KIT-simple_nowcast / **2022-03-29-KIT-simple_nowcast.csv**

dwolffram Update Baseline ✓ Latest comm

1 contributor

5337 lines (5337 sloc) | 472 KB

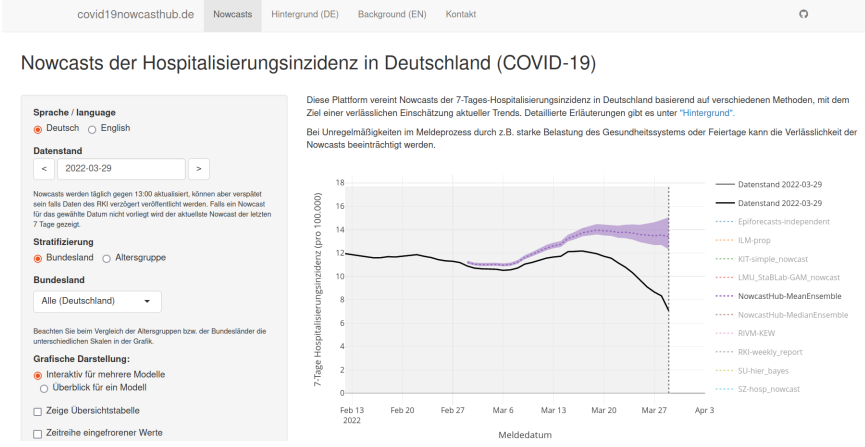
Search this file...

	location	age_group	forecast_date	target_end_date	target	type	quantile	value	pathogen
2	DE	00+	2022-03-29	2022-03-29	0 day ahead inc hosp	mean	NA	10642	COVID-19
3	DE	00+	2022-03-29	2022-03-29	0 day ahead inc hosp	quantile	0.025	8521	COVID-19
4	DE	00+	2022-03-29	2022-03-29	0 day ahead inc hosp	quantile	0.1	9131	COVID-19
5	DE	00+	2022-03-29	2022-03-29	0 day ahead inc hosp	quantile	0.25	9753	COVID-19
6	DE	00+	2022-03-29	2022-03-29	0 day ahead inc hosp	quantile	0.5	10534	COVID-19
7	DE	00+	2022-03-29	2022-03-29	0 day ahead inc hosp	quantile	0.75	11413	COVID-19
8	DE	00+	2022-03-29	2022-03-29	0 day ahead inc hosp	quantile	0.9	12292	COVID-19

`https://github.com/KITmetricslab/hospitalization-nowcast-hub/tree/main/data-truth/COVID-19`

Interactive online platform

https://covid19nowcasthub.de/



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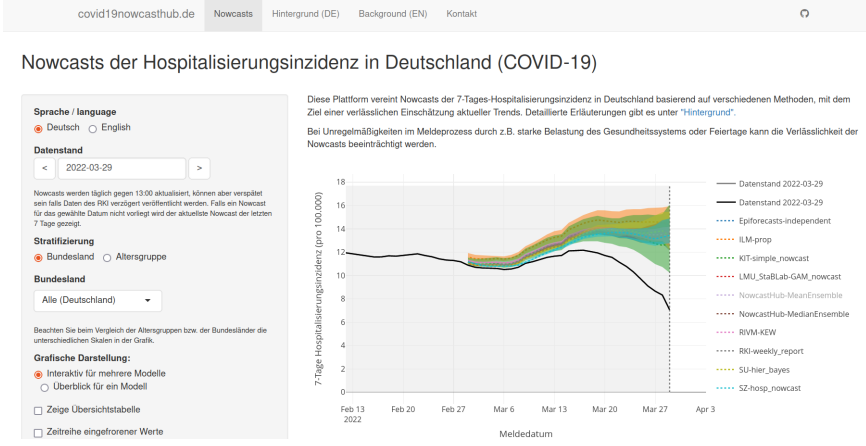

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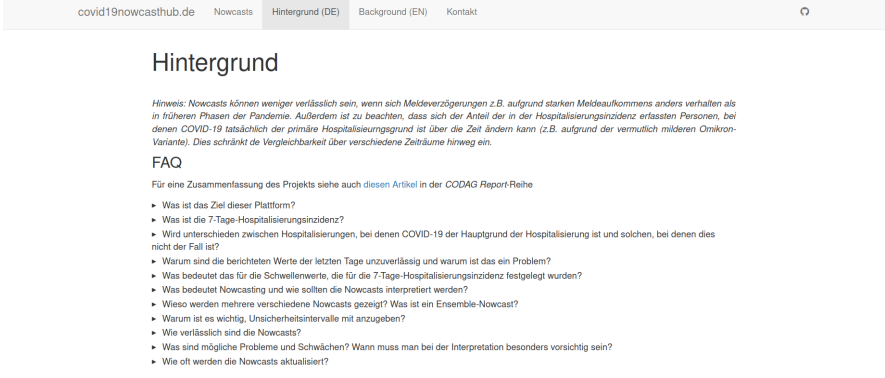


The statistical problem: completing the reporting triangle

Example with maximum reporting delay of 5 days. On day t^*, the black cells are known, the blue cells need to be estimated.

day	$d=0$	$d=1$	$d=2$	$d=3$	$d=4$	$d=5$	total
1	$x_{1,0}$	$x_{1,1}$	$x_{1,2}$	$x_{1,3}$	$x_{1,4}$	$x_{1,5}$	x_1
2	$x_{2,0}$	$x_{2,1}$	$x_{2,2}$	$x_{2,3}$	$x_{2,4}$	$x_{2,5}$	x_2
$\vdots$							
t^*-5	$x_{t^*-5,0}$	$x_{t^*-5,1}$	$x_{t^*-5,2}$	$x_{t^*-5,3}$	$x_{t^*-5,4}$	$x_{t^*-5,5}$	x_{t^*-5}
t^*-4	$x_{t^*-4,0}$	$x_{t^*-4,1}$<	$x_{t^*-4,2}$	$x_{t^*-4,3}$	$x_{t^*-4,4}$	$x_{t^*-4,4}$	x_{t^*-4}
t^*-3	$x_{t^*-3,0}$	$x_{t^*-3,1}$	$x_{t^*-3,2}$	$x_{t^*-3,3}$	$x_{t^*-3,4}$	$x_{t^*-3,5}$	x_{t^*-3}
t^*-2	$x_{t^*-2,0}$	$x_{t^*-2,1}$	$x_{t^*-2,2}$	$x_{t^*-2,3}$	$x_{t^*-2,4}$	$x_{t^*-2,5}$	x_{t^*-2}
t^*-1	$x_{t^*-1,0}$	$x_{t^*-1,1}$	$x_{t^*-1,2}$	$x_{t^*-1,3}$	$x_{t^*-1,4}$	$x_{t^*-1,5}$	x_{t^*-1}
t^*	$x_{t^*,0}$	$x_{t^*,1}$	$x_{t^*,2}$	$x_{t^*,3}$	$x_{t^*,4}$	$x_{t^*,5}$	x_{t^*}

Approaches taken by different teams

Three main sources of information on unknown values:

- incomplete hospitalization numbers for same day
- (incomplete hospitalization numbers from surrounding days
- number of cases

Strategies to extrapolate the reporting triange:

- Multiplication factors (KIT; the *reference model*, RKI, SZ) ●
- Regression with splines for smooth time trends (RIVM, LMU) ● ●
- Random walk / autoregressive approaches with parametric reporting delays (LSHTM, SU) ● ●
- Regression on case incidences (TU Ilmenau) ●

Example 1: The KIT model (“baseline”)

Three simple steps (similar to e.g. England and Verrall 2002):

- Fill in missing entries of reporting triangle using simple multiplication scheme:

day	$d = 0$	$d = 1$	$d = 2$	$d = 3$	total
1	$x_{1,0}$	$x_{1,1}$	$x_{1,2}$	$x_{1,3}$	x_1
2	$x_{2,0}$	$x_{2,1}$	$x_{2,2}$	$x_{2,3}$	x_2
$\vdots$					
$t^* - 2$	$x_{t^*-2,0}$	$x_{t^*-2,1}$	$x_{t^*-2,2}$	$x_{t^*-2,3}$	x_{t^*-2}
$t^* - 1$	$x_{t^*-1,0}$	$x_{t^*-1,1}$	$x_{t^*-1,2}$	$x_{t^*-1,3}$	x_{t^*-1}
t^*	$x_{t^*,0}$	$x_{t^*,1}$	$x_{t^*,2}$	$x_{t^*,3}$	x_{t^*}

E.g., $x_{t^*,1} = \frac{\sum_{i=1}^{t^*-1} x_{t^*-i,1}}{\sum_{i=1}^{t^*-1} x_{t^*-i,0}} \times x_{t^*,0}$

- Compute the same “estimates” for past time points, using data available up to the respective day.
- Obtain prediction intervals from past nowcast errors. *This is actually more tricky than it sounds.*

Example 2: The SU model (slide by F. Guenther)

Nowcasting - Bayesian hierarchical model

Notation

Main assumptions: (1) hospitalization curve is somewhat "smooth"
(2) delay patterns between infection and hospitalization constant
No assumptions on time-constant case hospitalization rate.

- $\lambda_{t,s}$: expected number of hospitalizations in strata s with infection registration at day $t = 0, \ldots, T$
- $p_{t,d,s}$: probability of individual (from group s) with registration at day t to be reported as hospitalized with delay $d = 0, \ldots, D$ (of all individuals that will become hospitalized)

delay distribution is modelled in a parametric fashion

Bayesian hierarchical model

Building up on Höhle [1], McGough [2], and Günther [3]

Latent random walk governing the overall hospitalization curve (= smoothness assumpt.)

$$\log(\lambda_{t,s})|\lambda_{t-1,s} \sim \mathrm{N}(\log(\lambda_{t-1,s}) + \beta_{wd(t)}, \sigma_s^2)$$

$$n_{t,d,s}|\lambda_{t,s}, p_{t,d,s} \overset{iid}{\sim} \mathrm{NB}(\lambda_{t,s} \cdot p_{t,d,s}, \phi_s)$$

Hospitalizations with different delays modelled depending on delay distribution and latent random walk

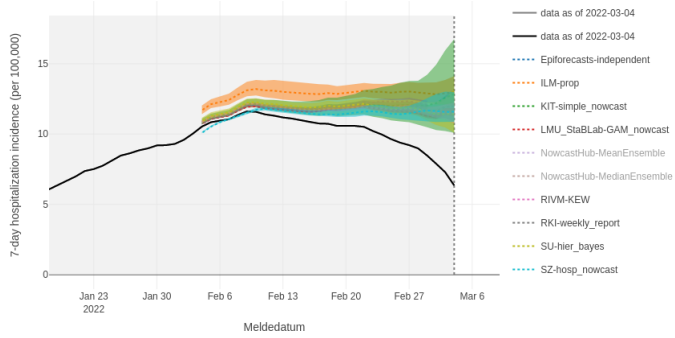
- $n_{t,d,s}$: observed data for all $t + d \leq T$
- $p_{t,d}$ modelled discrete time hazard model

Additional difficulties I smoothed over

- Two types of within-week seasonality need to be taken into account:
  - seasonality in reporting of cases
  - seasonality in reporting of hospitalizations
- Delay patterns change over time, so choosing an appropriate data subset for trainint is important.
- Occasional major reporting issues can mess up things.

The ensemble

- The main output of the platform is an **ensemble nowcast**, i.e. combination of all available models
- It is obtained as a simple quantile-wise mean (or median) of the different submissions.
- Intuition: We hope that similarly many models will be off upwards and downwards.



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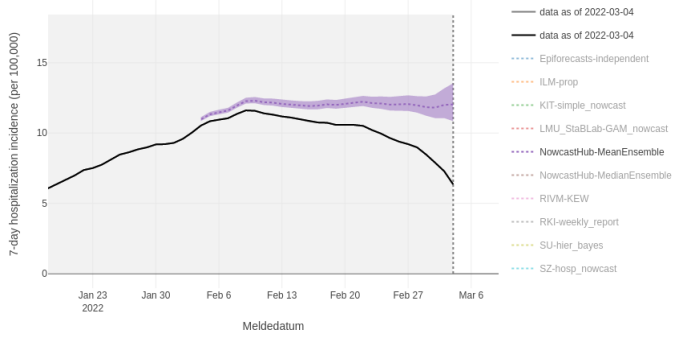
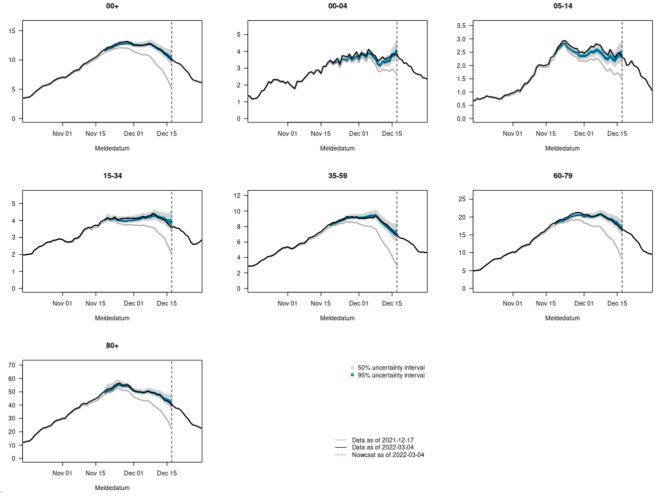


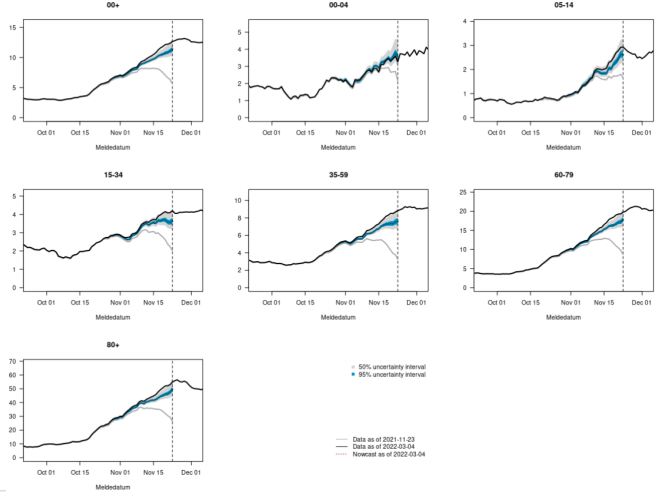
How well do the nowcasts work?

Nowcasts from December 17:

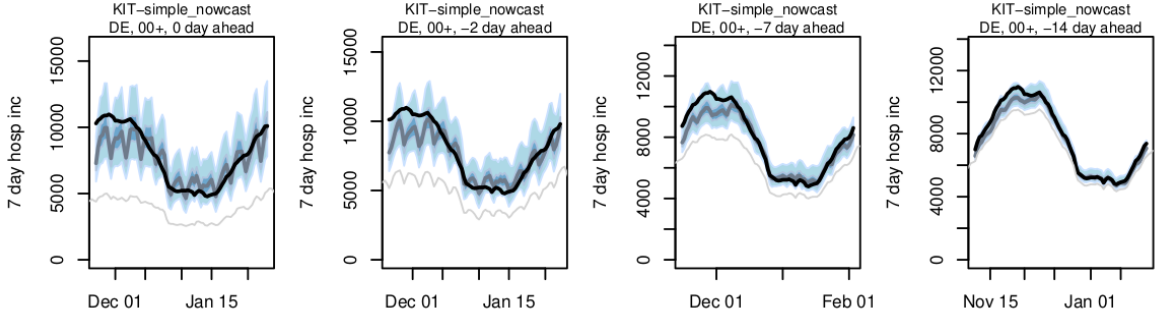


How well do the nowcasts work?

Nowcasts from November 23:



How well do the nowcasts work? (2)



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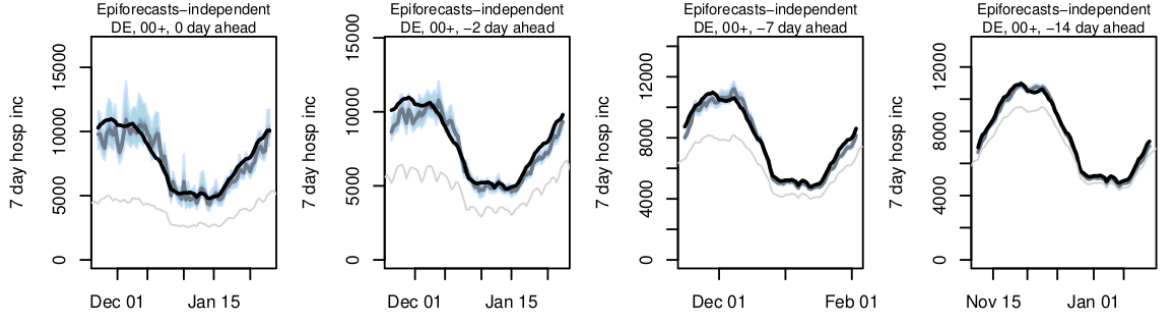

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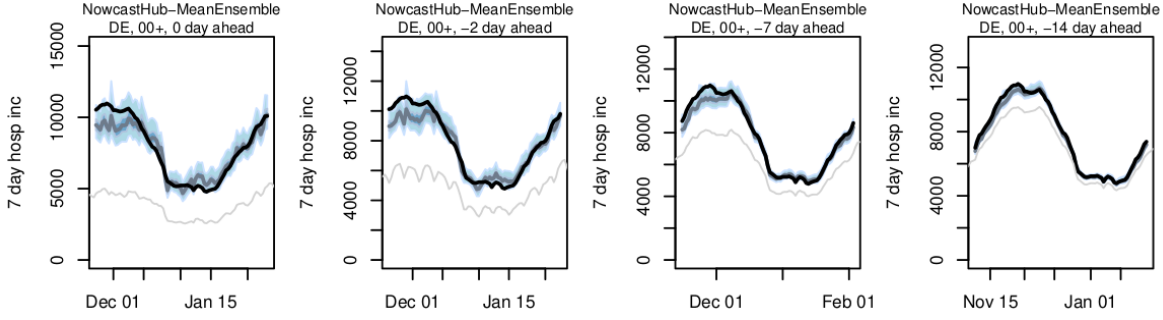
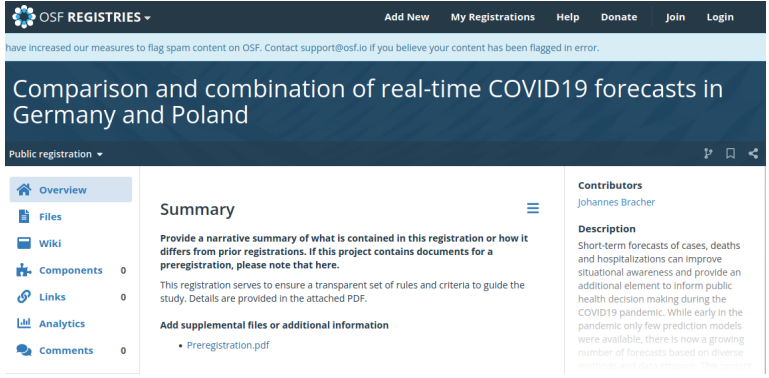


Prospective evaluation study

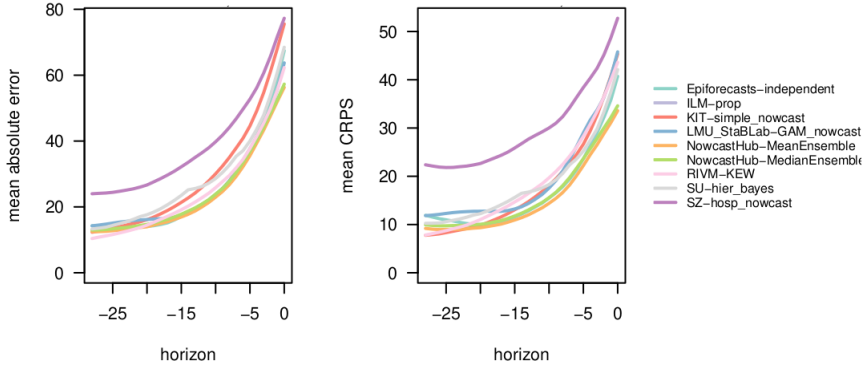
- We are conducting a systematic evaluation study of real-time nowcasts from different methods
- This study has been pre-registered (`https://osf.io/mru75/`) and runs from Nov 2021 through Apr 2022



Systematic evaluation of point and probabilistic nowcasts

We use absolute errors and (approximate) CRPS to evaluate nowcasts probabilistically (lower is better).

Preliminary results (until 10 Feb 22) averaged across states:

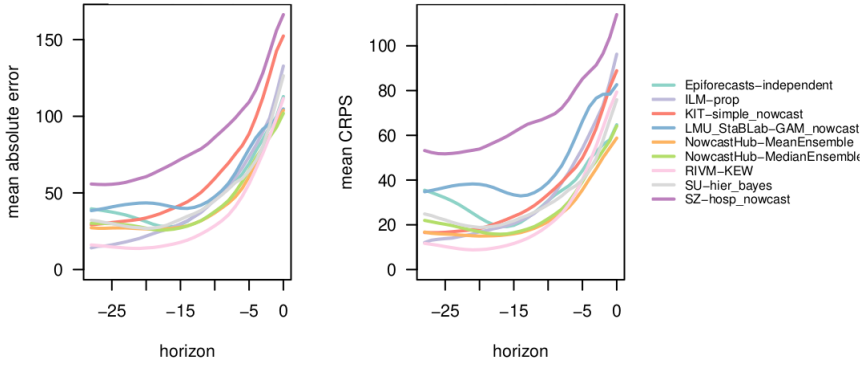


See also real-time evaluation by Sam Abbott:
`https://epiforecasts.io/eval-germany-sp-nowcasting/real-time-method-comparison/`

Systematic evaluation of point and probabilistic nowcasts

We use absolute errors and (approximate) CRPS to evaluate nowcasts probabilistically (lower is better).

Results (until 10 Feb 22) averaged across age groups:



See also real-time evaluation by Sam Abbott:
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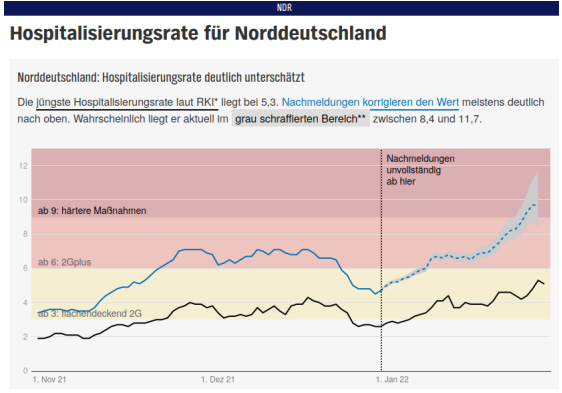
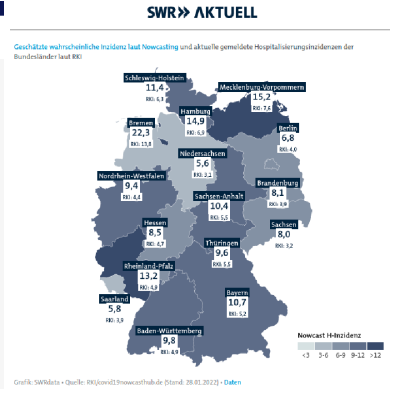
Preliminary takeaways

- In most cases, nowcasts have conveyed a good picture of actual trends.
- Most methods, however, have issued somewhat overconfident uncertainty intervals.
- In some instances (e.g., in Saxony in November), nowcasts have been strongly off, but these are often predictable as due to known issues with the reporting system (so users can be warned).
- Ensemble nowcasts improve somewhat, but not drastically upon individual models.
- **Collaborative work is rewarding and instructive.**

Dissemination

- The nowcasts have been used by numerous media outlets (Die Zeit, Süddeutsche Zeitung, Der Spiegel, Focus, Science Media Center Germany)





Communication is challenging

We try to provide accessible documentation (`https://covid19nowcasthub.de/hintergrund.html`), but communicating the concept of nowcasting to a broader public is not always straightforward.

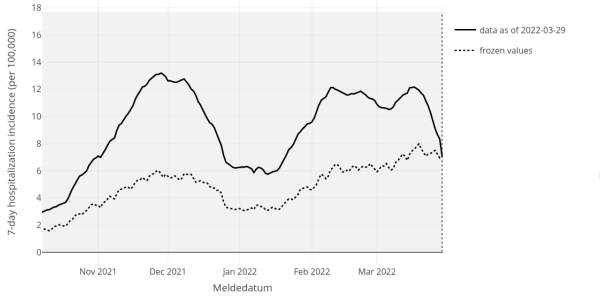
References

- Bracher and Wolffram (2021): Preregistration – Comparison and combination of COVID-19 hospitalization nowcasts in Germany. `https://osf.io/8mksf`.
- England and Verrall (2002): Stochastic Claims Reserving in General Insurance. British Actuarial Journal 8(3): 443 – 518.
- Günther, Bender, Katz, Küchehoff, Höhle (2021): Nowcasting the COVID-19 pandemic in Bavaria. Biometrical Journal 63(3): 490–502.
- Höhle and an der Heiden (2014): Bayesian nowcasting during the STEC O104:H4 outbreak in Germany, 2011. Biometrics 70(4): 993–1002.

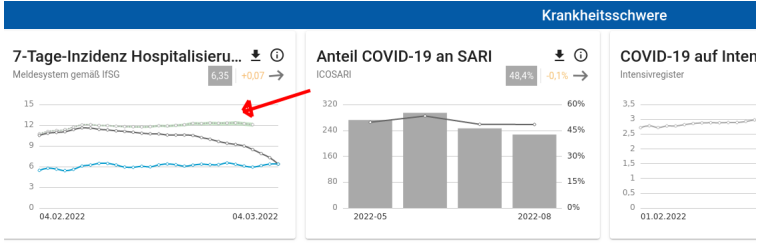
On a side note: “frozen values”

Official thresholds are based on *frozen values*:

- For each date use value as of that same date, without any retrospective completion
- All values are then “similarly incomplete” $\rightarrow$ trends interpretable
- Downsides:
  - reporting delays vary across Bundesländer
  - strong within-week seasonality



Corrected hospitalization incidences by Robert Koch Institute



Altersgruppen

Name	7-Tage-Inzidenz			Änderung 7-Tage-Inzidenz zu Vorwoche			Positivenanteil		
	Wert	Differenz	Trend	Wert	Differenz	Trend	Wert	Differenz	Trend
00-04	1.067,3	-43,18	↘	-4,02%	+4,43%	→	38,5%	+1,7%	→
05-14	1.973,5	-361,57	↘	-15,48%	+2,86%	→	62,6%	-0,6%	→

Corrected hospitalization incidences by Robert Koch Institute