**Forschung und Entwicklung - Abteilung Meteorologische Analyse und Modellierung**
Operatioal NWP-System: ICON

## Near-surface visibility diagnostic

Starting **Tuesday, April 23rd 2024, at 09 UTC** the output variable VIS (near-surface visibility) will be available from ICON-D2 and ICON-EU.

An interest in near-surface visibility forecasts was put forward by the aviation forecasting offices of DWD. This parameter is routinely used, together with ceiling (lowest level, where cloud cover exceeds 50%) to forecast conditions near airports and for VFR (visual flight rule) aviation in general. Further there was an interest in having these two parameters (VIS and ceiling) as routine verification metrics, since they yield relevant information about the boundary layer, especially in stable conditions. While ceiling was already available as output parameter, a visibility diagnostic had to be implemented in the ICON model. After implementation and further calibration, visibility has been monitored for a three month period in winter 2023/2024. Its behavior was found to be consistent with expectations, in particular the frequency of events compares well with observations.

The visibility diagnostic itself consists of two parts:

1. Visibilities below about 1-2 kilometers are dominated by hydrometeors. Here warm fog is dominant, while precipitation also contributes, at least over the ICON-D2 and ICON-EU domains. The visibility dependence on hydrometeor partial densities is modeled according to [1]. The partial densities are available at runtime.
The respective extinction coefficient $\beta$ for a given hydrometeor is then obtained after [1] as:

$$\beta = a\,C^b$$

where $C$ is the respective partial density and $a$ and $b$ are empirical coefficients.

The visibility is then obtained via the Koschmieder relation:

$$VIS = \frac{-ln 0.02}{\beta}$$

2. Visibilities in the range 2-10 kilometers are dominated by haze. Here the modeling is more difficult. Inspired by [2] we parameterize visibility as function of relative humidity. The functional form was obtained by calibrating against one month of surface observation over the ICON-D2 domain. Standard relations found in the literature (e.g. [2]) turned out to have a strong frequency bias in the ICON-D2 domain.

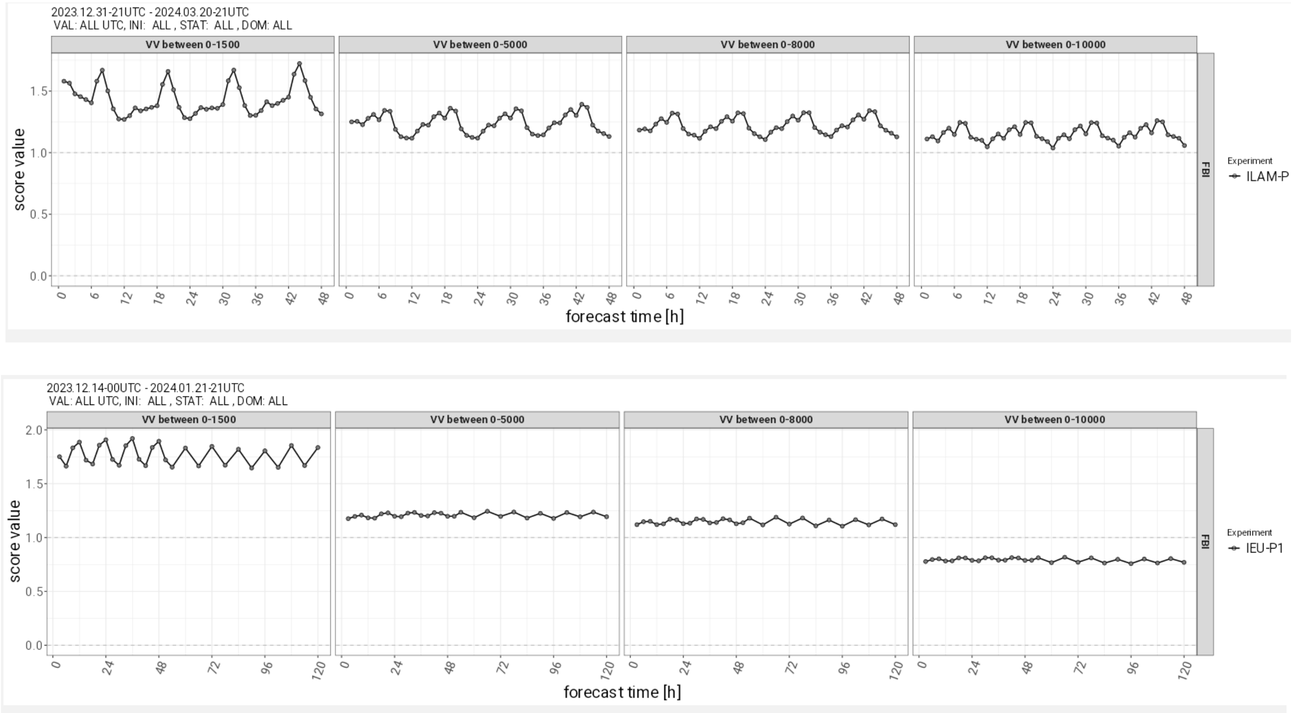


Figure 1: Frequency bias (FBI) for visibility (VV in the figure) for the main warning thresholds 1500 m, 5 km, 8 km, 10 km, i.e. the relative frequency of events with visibility below that threshold. Data covers the range from January 1st, 2024 till March 20th, 2024. Top: ICON-D2, January 1st, 2024 till March 20th, 2024. Bottom: ICON-EU, December 14th till January 21st 2024. The category <1500 m (dominated by fog) shows some moderate over forecasting (factor 1.5, both models). In the categories dominated by haze (1500 m < VV < 10 km) the FBI is quite close to unity, especially for ICON-D2, for whose domain the calibration was designed.

[1] Kunkel, Bruce A. "Parameterization of droplet terminal velocity and extinction coefficient in fog models." *Journal of Applied Meteorology and Climatology* 23.1 (1984): 34-41.

[2] Gultepe, Ismail, et al. "The fog remote sensing and modeling field project." *Bulletin of the American Meteorological Society* 90.3 (2009): 341-360.

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