

METEOROLOGISKA INSTITUTET INNISH METEOROLOGICAL INSTITUTE

Probability, uncertainty and forecast skill Marko Laine, FMI

PNOWWA webinar 2017-10-04



- "The probability that it rains tomorrow is 20%"
- deterministic) events, like a tossing of coin or gambling.
- most cases, we use probability to quantify uncertainty.
- Weather and climate are complicated phenomena. We need a notion of chaos and predictability.
- philosophical disputes here.]

What is probability

• **Classical interpretation** as long run frequencies. Relevant for simple, repeatable (and

• Probability as a (subjective) measure of degree of belief, aka the **Bayesian interpretation**.

When talking about a single future event, there is no direct frequentistic interpretation. In

[Mathematically, probability is finite and additive measure, defined for a set of events. No





Difficulties with probabilities

- Probabilities, especially conditional probabilities, can fool our intuition.
- "Thinking, Fast and Slow" by Daniel Kahneman:
 - People overestimate rare probabilities.
 - Adding more information, makes the scenario more plausible.
 - Risk policies are difficult, as we tend to avoid immediate losses.
- Simpson's paradox. Change in the background assumptions, e.g. different climatologies.

Probability of thunderstorm in Helsinki tomorrow at 12.

Choose between: A. sure gain of \$240 B. 25% chance to gain \$ 1,000



Uncertainty in forecasts

- Natural variability of weather. Climatology as the historical distribution.
- Forecast skill is reduction of uncertainty with respect to a reference/trivial forecast.
- NWP models have uncertainties and inaccuracies for several reasons.
 1. Limited number or observations to initialize the model.
 - 2. Model resolution does not allow to resolve all important spatial and temporal scales.
 - 3. Uncertainty in the model parameterizations.
- Uncertainty quantification is done by using statistical probability distributions.





ILMATIETEEN LAITOS Meteorologiska institutet Finnish meteorological institute

How to make probability forecasts

- Probabilities for an event based on an ensemble of predictions from NWP models.
- Statistical post-processing of NWP output from a single model run or the output of ensemble-based NWP.
- By analysis of historical weather and climate data to yield statistical relationships between currently observable predictors and the future observations of interest.
- Meteorologist subjective interpretation of NWP forecasts and other information.





Probability forecasts

"There is 20% probability for rain exc AM, at Kumpula, Helsinki."

- The meteorologist best opinion (but might fear feedback for false negatives).
- Of 50 ENS forecast members, 20% had heavy rain (but might not be calibrated).
- Of 5 different deterministic models, 1 forecasted rain (but they all use the same observations).
- In October, it usually rains 20% of the days in Helsinki (no skill).

"There is 20% probability for rain exceeding 5 mm, tomorrow between 9 -12





Ensemble forecasts

- Run the same forecast model with perturbed initial conditions.
- ENS system has to be tuned to match predictability and model's inaccuracies.
- Ensembles have to be **calibrated** to correct the spread and remove biases.

Probability 20% means that 10 out of 50 ensemble members predict more than 5mm of rain to fall at the specified location in the defined period.

ECMWF Ensemble forecasts Helsinki, Finland 60.23°N 25°E (ENS land point) 23 m High Resolution Forecast and ENS Distribution Monday 2 October 2017 00 UTC

Temperature at 850 hPa - Probability for 1°C intervals









How to verify probabilities

Reliability and ROC diagrams of one year of Probability of Precipitation forecasts. The reliability curve (with open circles) indicates strong over-forecasting bias throughout the probability range.



• When we do **repeated** probability statements, they can be verified by using actual observations. The forecasted probabilities have to match the observed frequencies (reliability). Several statistics and diagrams are used.

> The ROC curve is constructed on the basis of forecast and observed probabilities leading to different potential decision thresholds. The black dot represents the single value ROC when using 50% treshold (H=0.7; F=0.17).

> > Figures by Pertti Nurmi.





- event being forecast.
- negative predictions and want the risks for the both to be small.

• A probability forecast includes a numerical expression of uncertainty about the quantity or

• Uncertainty means risks of wrong decisions. We want to avoid false positive and false

	observed	not observed
forecasted	OK (hit)	false positive
not forecasted	false negative	OK





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0			
		observed	not observed
	forecasted	OK (hit)	false positive
A = 0.74	not forecasted	false negative	OK
0.6 0.8 1 rm rate 9			





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		observed	not observed
	forecasted	OK (hit)	false positive
A = 0.86	not forecasted	false negative	OK
0.6 0.8 1 alarm rate 9			





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Why probability forecasts

- To quantify the uncertainties related to forecasts.
- To better handle risks associated with different actions.
- "We want to be 95% sure that in the next 30 years the water level will rise more than 1 m from the average less that 2 times."
- To educate the public about uncertainties in forecasts.
- To have better verification measures, e.g. which account for the predictability.

