

# Probabilistic forecasting: The example of weather forecasts

Johanna F. Ziegel

University of Bern

23 September 2013

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# statistics



## INTERNATIONAL YEAR OF STATISTICS

RECOGNIZING THE CONTRIBUTIONS OF STATISTICS  
TO SOCIETIES WORLDWIDE

<http://statistics2013.org>

300 years ago...

JACOBI BERNOULLI,  
Profess. Basil. & utriusque Societ. Reg. Scientiar.  
Gall. & Pruss. Sodal.  
MATHEMATICI CELEBERRIMI,

**ARS CONJECTANDI,**  
OPUS POSTHUMUM.

*Accedit*  
**T R A C T A T U S**  
**D E S E R I E B U S I N F I N I T I S ,**

Et EPISOLA Gallicè scripta

**D E L U D O P I L Æ**  
**R E T I C U L A R I S .**



B A S I L E Æ ,  
Impensis THURNISIORUM, Fratrum  
cl<sup>o</sup> lccc xiii.

# Ars Conjectandi

- ▶ Jacob Bernoulli, 1655–1705.
- ▶ Work on Ars Conjectandi from 1684–1689, published 1713.
- ▶ Transferred the mathematics of games of chance to probabilities of real world events.

*Probability is a degree of certainty, and differs from certainty as a part from the whole.*

International Conference Ars Conjectandi 1713–2013  
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RECOGNIZING THE CONTRIBUTIONS OF STATISTICS TO SOCIETY WORLDWIDE



[www.statistics2013.org](http://www.statistics2013.org)



Without Statistics we wouldn't know  
how to dress for the weather.

# Probabilistic weather forecasts

- ▶ The weather forecast of *Tagesanzeiger* for Bern today at 15:00 stated this morning at 6:52 that
  - the temperature will be 20°C,
  - and there is a 0% chance of rain.
- ▶ There is a conceptual difference between these two forecasts:
  - ▶ The temperature forecast is a **point forecast**.
  - ▶ The “chance of rain” forecast is a **probabilistic forecast**.

# Probabilistic forecasts

J. Bernoulli, Ars Conjectandi:

*We define the art of conjecture, or stochastic art, as the art of evaluating as exactly as possible the probabilities of things, so that in our judgments and actions we can always base ourselves on what has been found to be the best, the most appropriate, the most certain, the best advised; this is the only object of the wisdom of the philosopher and the prudence of the statesman.*

Abramson and Clemen (1995), International Journal of Forecasting:

*Saying that forecasts should incorporate uncertainty is like saying that governments should reduce waistful spending.*

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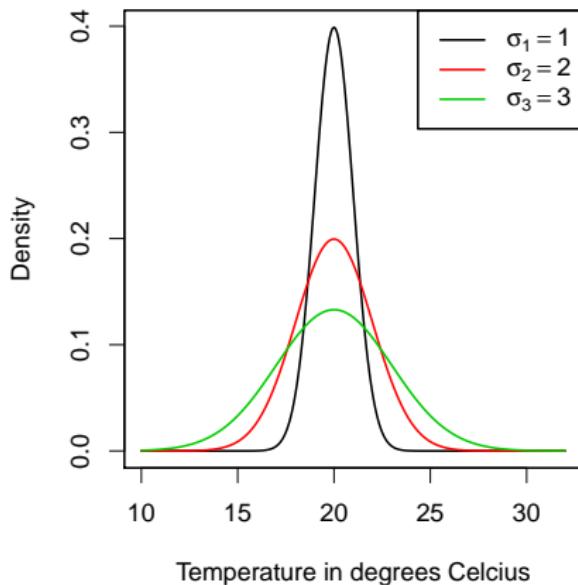
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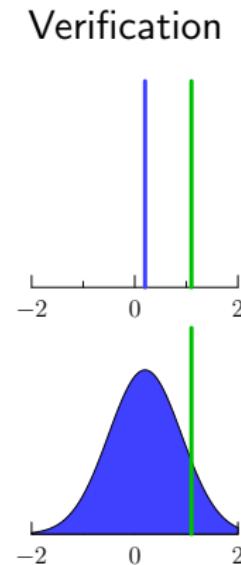
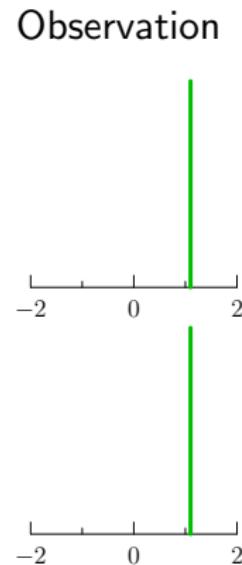
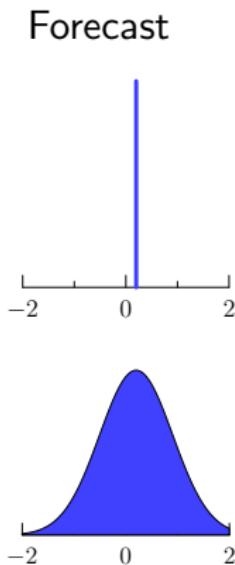
*Saying that forecasts should incorporate uncertainty is like saying that governments should reduce waistful spending.*

A **probabilistic forecast** for temperature could be: We predict that the temperature today at 15:00 will be distributed according to

$$\mathcal{N}(20, \sigma^2).$$



# Forecasts for real-valued quantities



80 years ago...

ERGEBNISSE DER MATHEMATIK  
UND IHRER GRENZGEBiete  
HERAUSGEgeben VON DER SCHRIFTLEITUNG  
DES  
„ZENTRALBLATT FÜR MATHEMATIK“  
ZWEITER BAND

— 3 —

GRUNDBEGRIFFE DER  
WAHRSCHEINLICHKEITS-  
RECHNUNG

von  
A. KOLMOGOROFF



BERLIN  
VERLAG VON JULIUS SPRINGER  
1933

## Prediction spaces

- ▶ Let  $\Omega$  denote the set of states of nature.
- ▶ Encode today's information for prediction by a  $\sigma$ -Algebra  $\mathcal{A}$ .
- ▶ Consider, both, the probabilistic forecasts  $F$  and the future event  $Y$  as random variables on  $\Omega$ , where  $F$  only depends on  $\mathcal{A}$ .

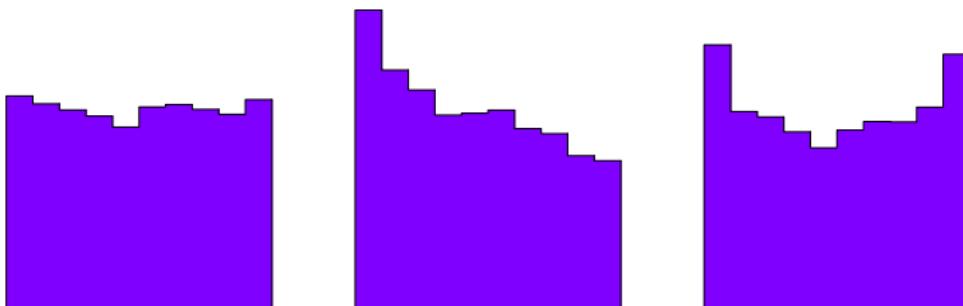
Now, we can do statistics!

## Calibration

If the observation  $Y$  has (continuous) distribution function  $F$  then

$$F(Y) \sim UNIF(0, 1).$$

This can be checked empirically with PIT histograms.



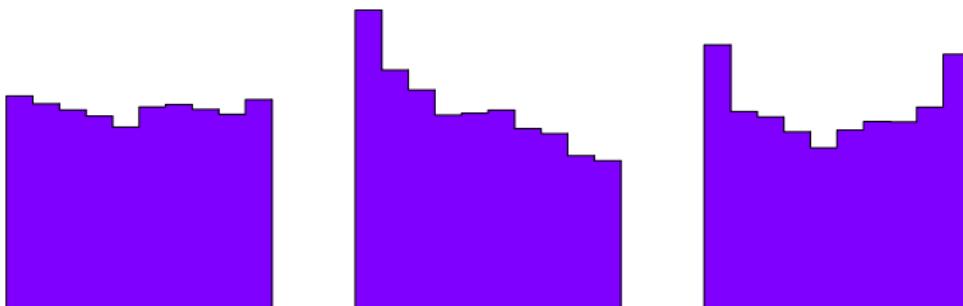
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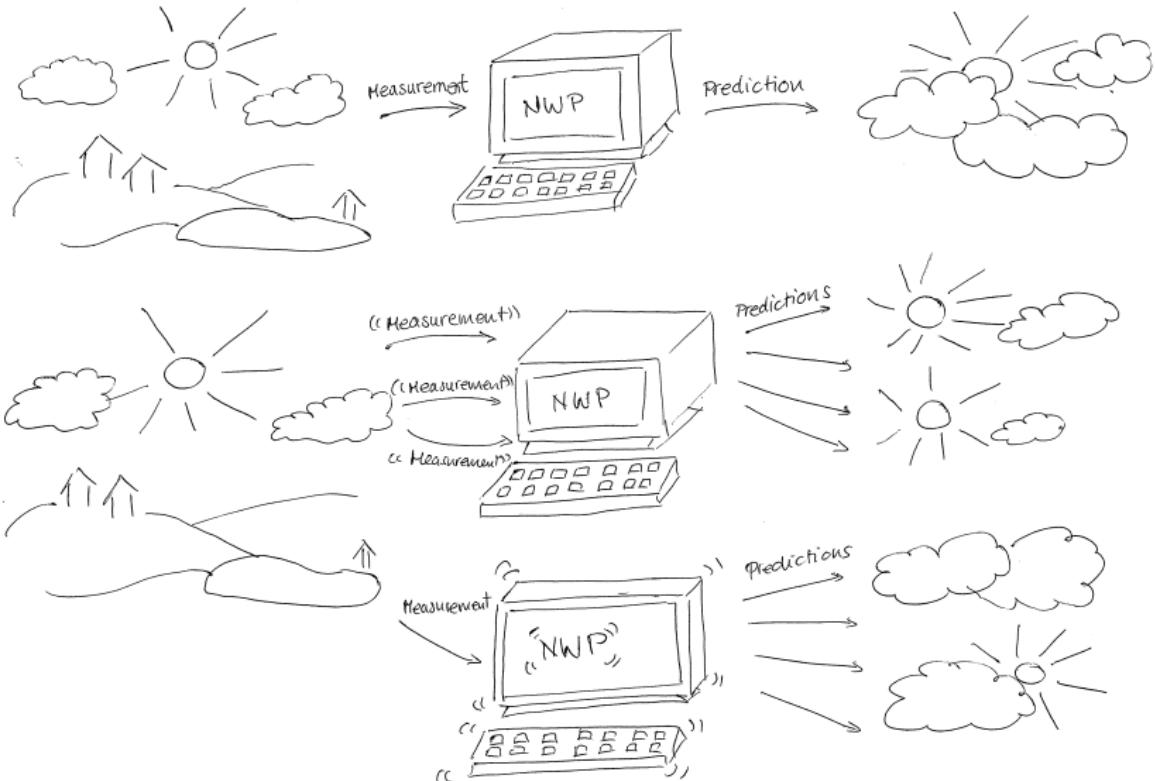
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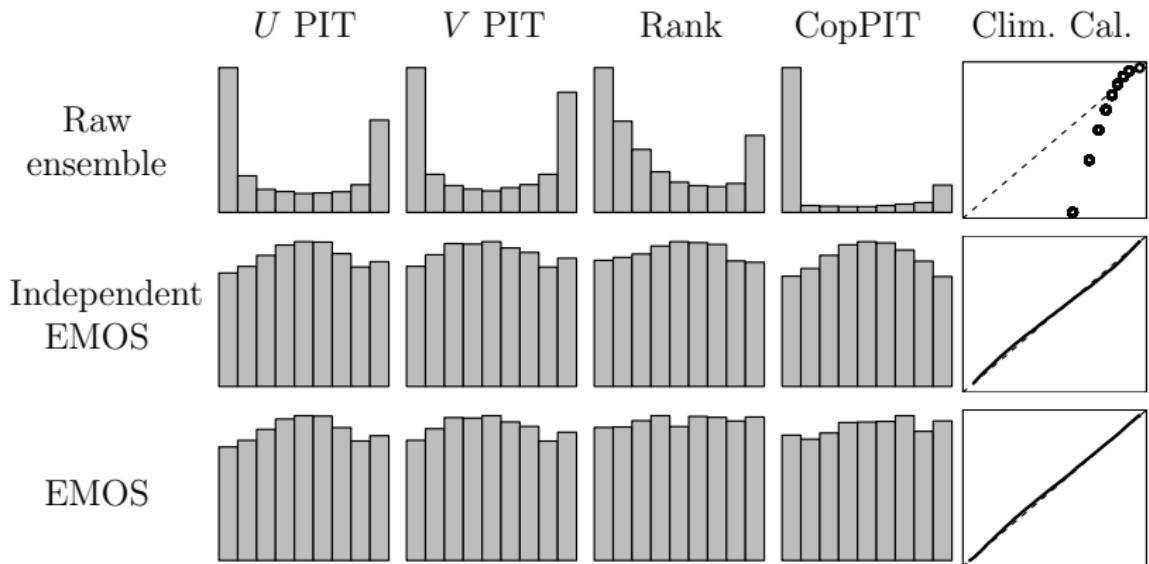
# Ensemble methods



## Wind vector predictions

- ▶ Probabilistic forecasts of surface wind vectors over the North American Pacific Northwest based on the University of Washington Mesoscale Ensemble.
- ▶ Test data of year 2008 with 19,282 forecast-observations pairs at a prediction horizon of 48 hours.
- ▶ Forecasts to compare:
  - ▶ Raw ensemble forecast (8 ensemble members).
  - ▶ Statistically postprocessed regional bivariate EMOS forecast (Schuh et al., 2012).
  - ▶ Independent EMOS forecast.

# Results for wind vectors



See Ziegel and Gneiting (2013), arXiv:1307.7650.

# Applications and challenges

- ▶ Statistical postprocessing of ensemble forecasts
- ▶ Interpretation of ensemble forecasts
- ▶ Combination of forecasts
- ▶ Multivariate forecasts
- ▶ Climate predictions
- ▶ Probabilistic forecasts for inflation, GDP growth,...
- ▶ Uncertainty in risk assessment

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# Current activities

- ▶ Interpretation of predictive probabilities  
Workshop on Probabilistic Modeling in Science and Philosophy  
11-12 October 2013, Bern
- ▶ Uncertainty in risk assessment  
Symposium on Uncertainty: from Insight to Action  
20–22 November 2013, EPF Lausanne
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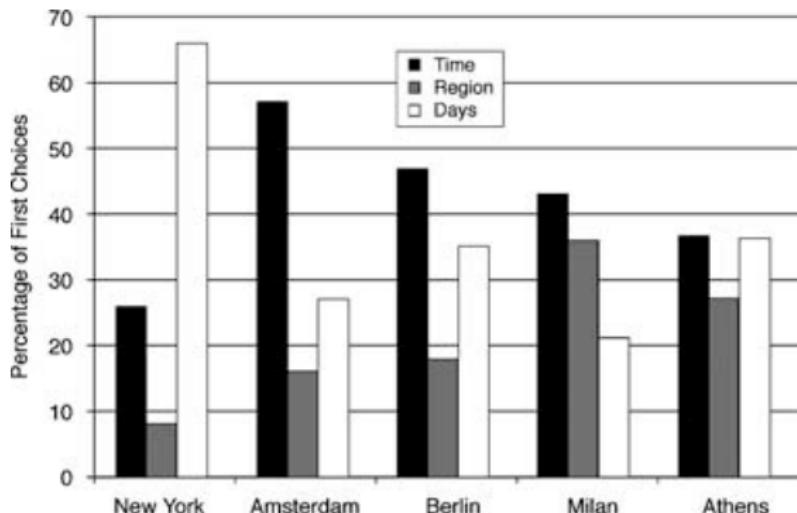
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# Communication of probabilistic forecasts

- ▶ Is it possible to communicate probabilistic forecasts to decision makers or the general public?
- ▶ Example concerning the general public:

There is a 30% chance of rain tomorrow.

# Communication of probabilistic forecasts



**Fig. 1.** First choice. People in New York ( $n = 103$ ), Amsterdam ( $n = 117$ ), Berlin ( $n = 219$ ), Milan ( $n = 203$ ), and Athens ( $n = 108$ ) were asked what the statement “There is a 30% chance of rain tomorrow” refers to. The three alternatives were “It will rain tomorrow for 30% of the time,” “in 30% of the region,” and “on 30% of the days like tomorrow.”

See Gigerenzer et al. (2005), Risk Analysis 25, 623–629.

## Quote

*We [statisticians] all have experienced the fascination and joy that the analysis of chance, data and uncertainty brings. We are aware of the astonishing achievements that have been made in our field and of the impact and importance it has on our society. We are also convinced that our field can contribute much to solve the challenges that we currently face. However, not all of this is recognized in other scientific areas and among the general public. In particular, statistics is still too often viewed as a dull, marginal or dubious activity with a potential for manipulation and distortion. Hence the International Year of Statistics gives us a platform to reach out and present a more accurate view of our field.*

IMS President, Hans Rudolf Künsch

Thank you for your attention!