FOGCAST

Probabilistic fog forecasting based on operational COSMO-DE model

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COSMO/CLM User Seminar

DWD, Offenbach/Main, 19 March 2014

Motivation

- Fog = small scale phenomenon

- Sophisticated 3D fog models
  + advanced microphysical parameterization schemes
  + high vertical resolution
  + promising results
  - CPU time beyond the range of an operational setup

- Testbed for COSMO-DE to identify which model parameterization contains skill for fog forecast

- → Find an optimal set up of COSMO-DE for operational fog forecasts

Outline

COSMO-DE forecasts

First Step: Fog Stability Index
Deterministic approach

From FSI to FOGCAST
Probabilistic approach

Conclusions and Outlook

Fog Stability Index

Fog **S**tability **I**ndex (Air Weather Service (1979))

$$FSI = 2 \cdot (T - T_d) + 2 \cdot (T - T_{850}) + V_{h,850}$$

Dewpoint spread

Horizontal wind speed at 850 hPa

Vertical temperature gradient

Fog risk

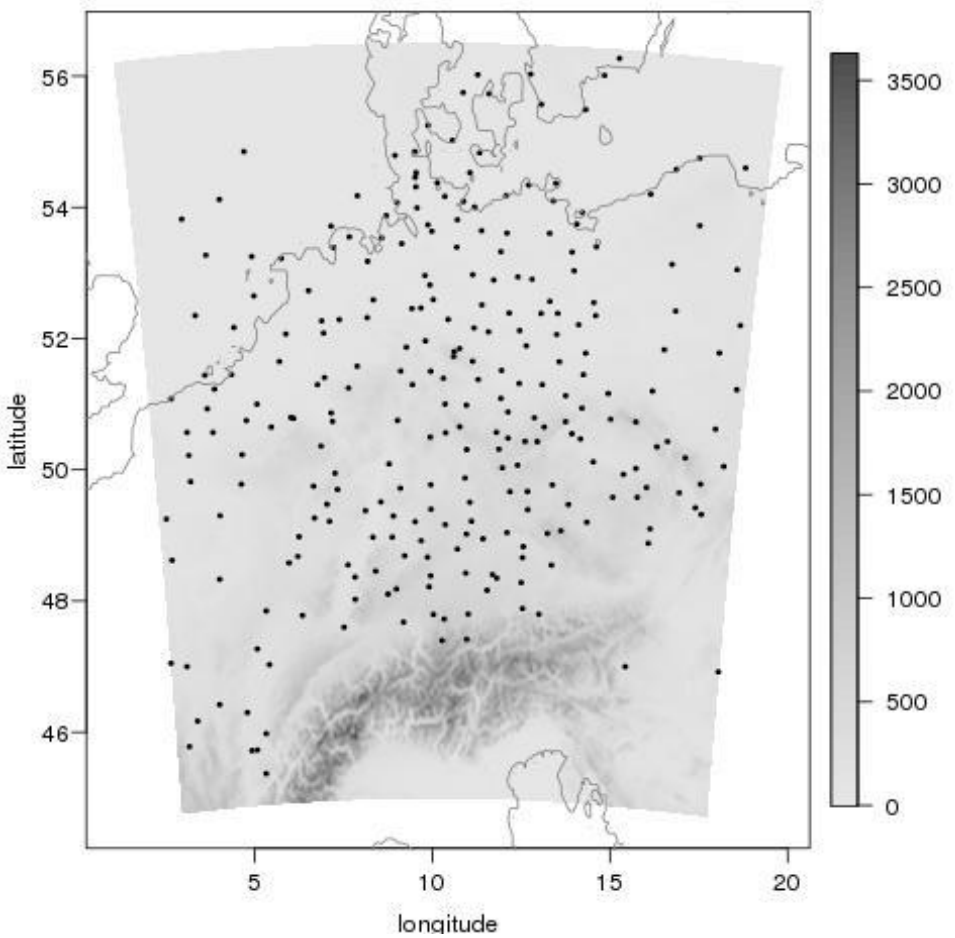
$FSI < 31$ $\quad 31 < FSI < 55$ $\quad FSI > 55$

Apply FSI to COSMO-DE forecasts for 2011
(initialized at 00 UTC, 21 hours)

Data for Verification

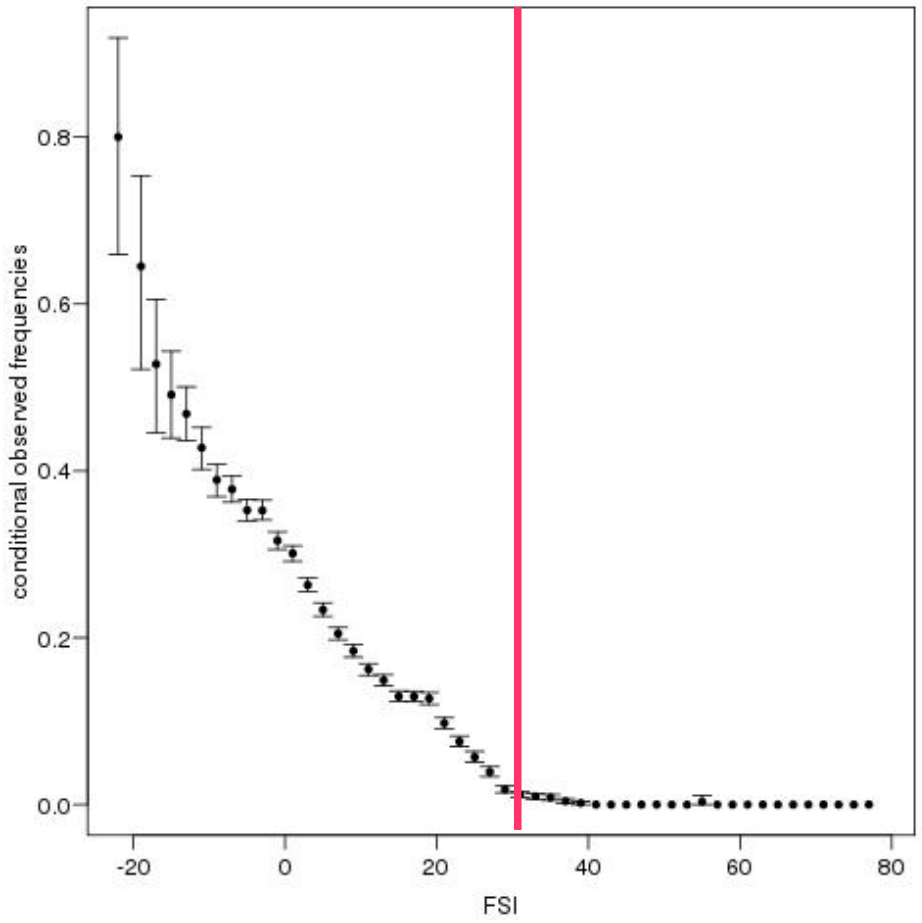
SYNOP stations

- Hourly measurements of visibility
- 269 stations
- Fog – **Yes?** or **No?**
  VIS ≤ 1000 m

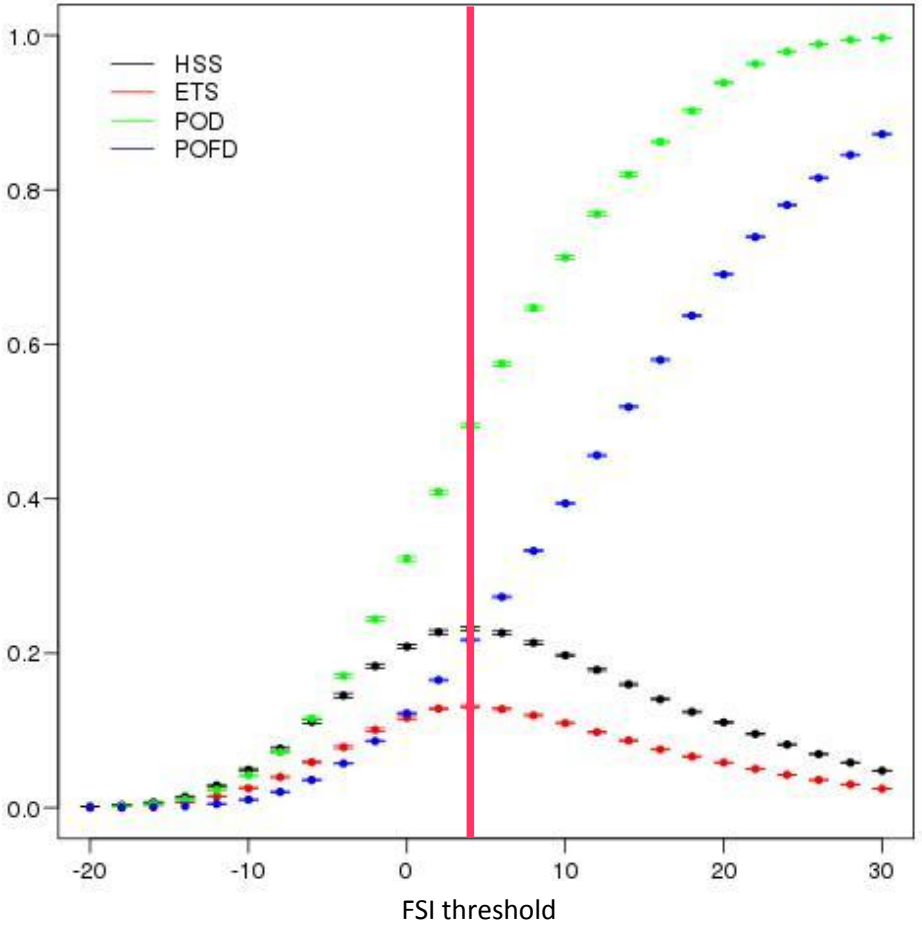


FSI and Visibility – November 2011

Conditional observed frequency

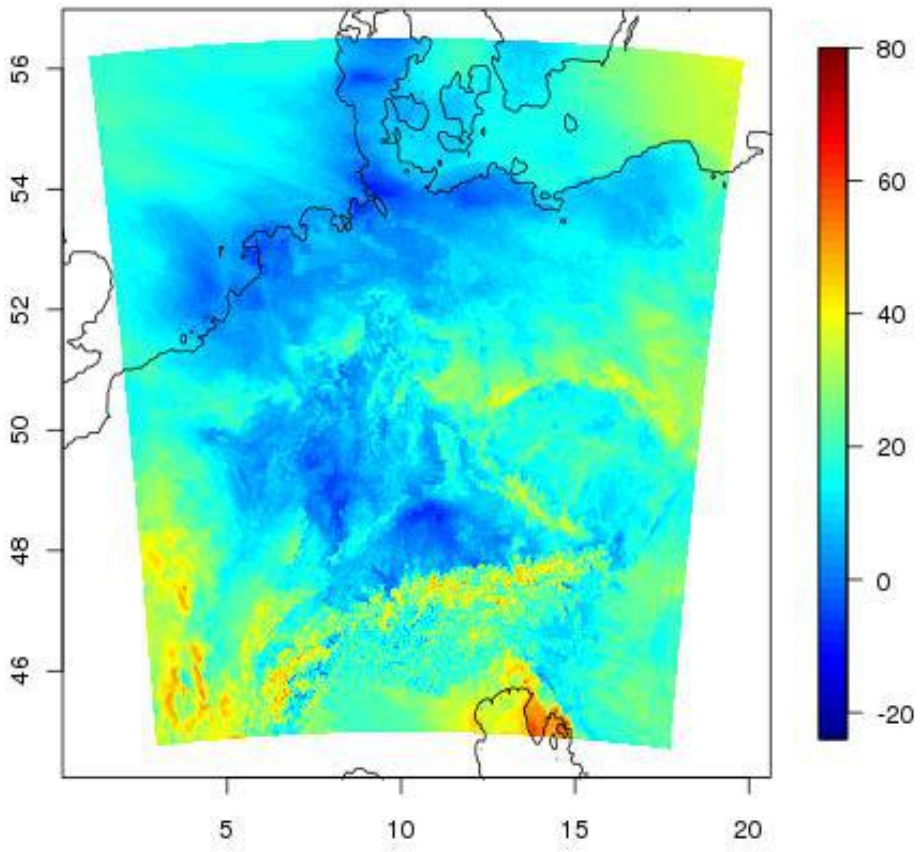


Scores from contingency table

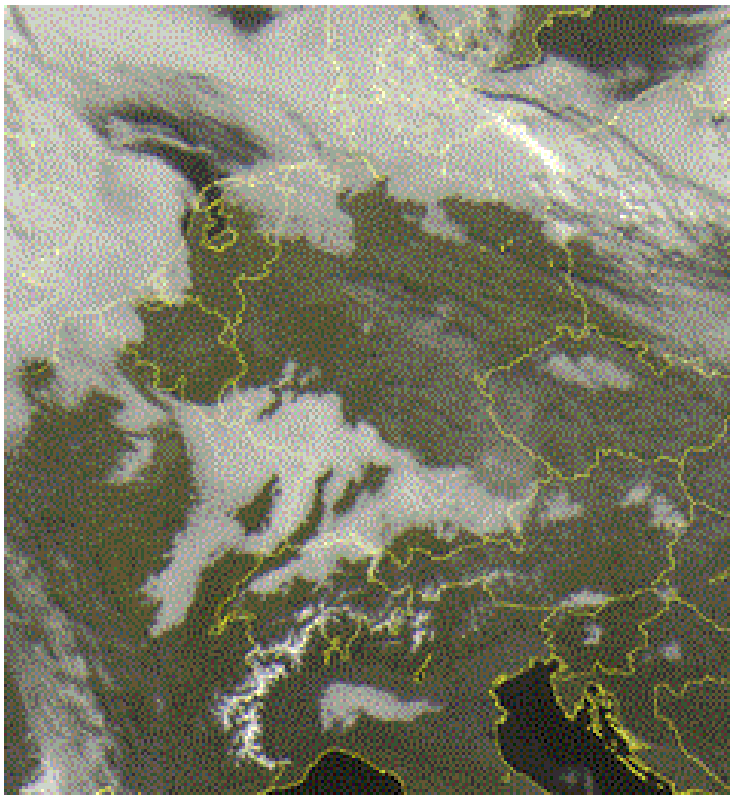


Fog event over Germany

14.11.2011 12 UTC



FSI (COSMO-DE forecasts)



Source: www.sat24.de

Visible channel MSG

FOGCAST

- Learning from history data: relate observation y_i and covariates x_i
- **Generalized linear models**
  - linear predictor: $\eta_i = \vec{x}_i^{\,T} \cdot \vec{\beta}$
  - logistic regression: $\pi = P(y=1|x) = h(\eta) = \frac{\exp(\eta)}{1+\exp(\eta)}$

⟶ **Fog probability**

- **Verification based on Brier score:** $BS = \frac{1}{N}\sum_{i=1}^{N}(\pi_i - y_i)^2$

Binary observation

Forecast probability

FOGCAST

- **L**east **A**bsolute **S**hrinkage and **S**election **O**perator (Tibshirani (1996))

- Penalized regression

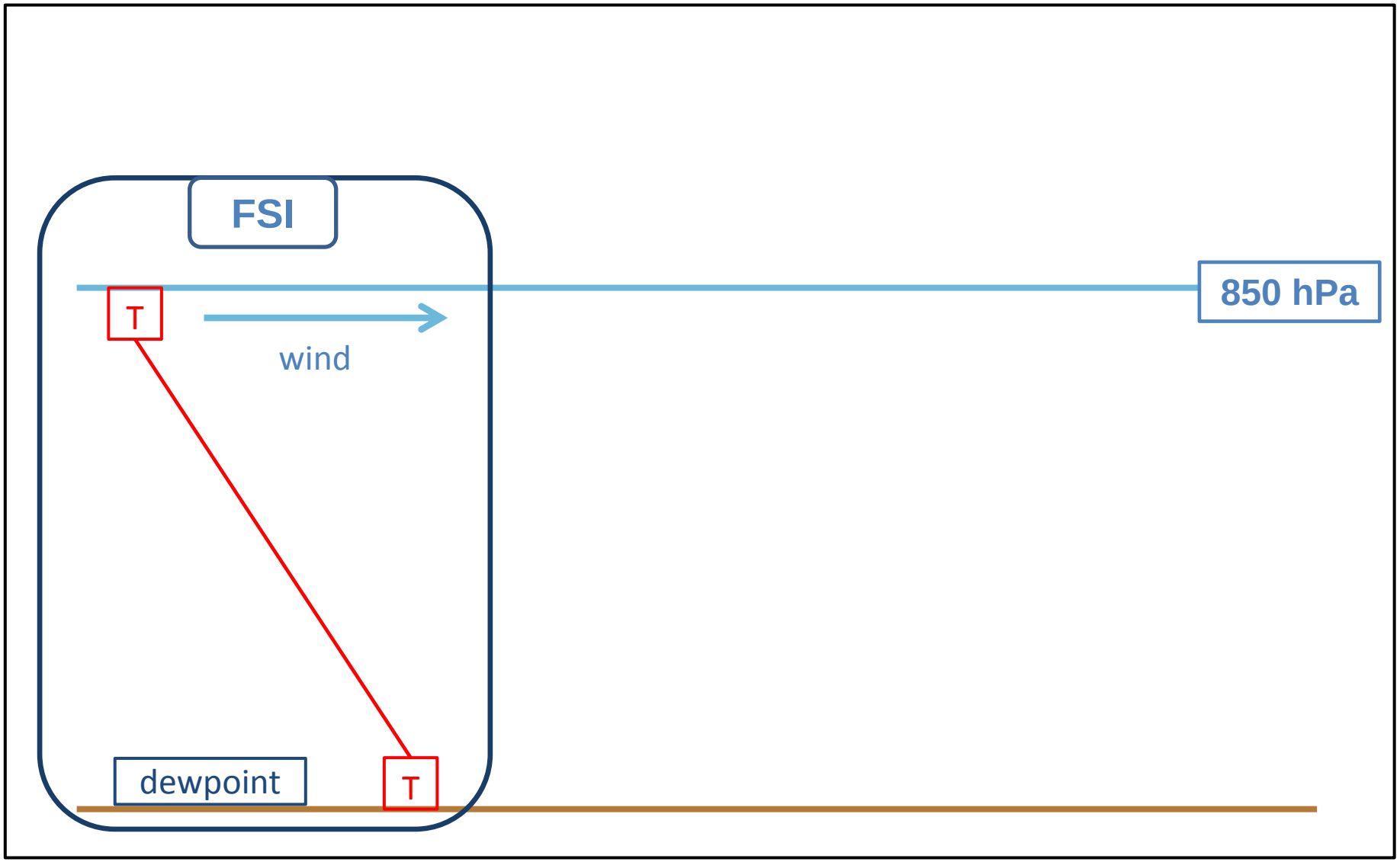
$$\hat{\beta} = \arg\min_{\beta} \left\{ -l(\beta) + \lambda \sum_{j=1}^{p} |\beta_j| \right\}$$

LASSO Penalty

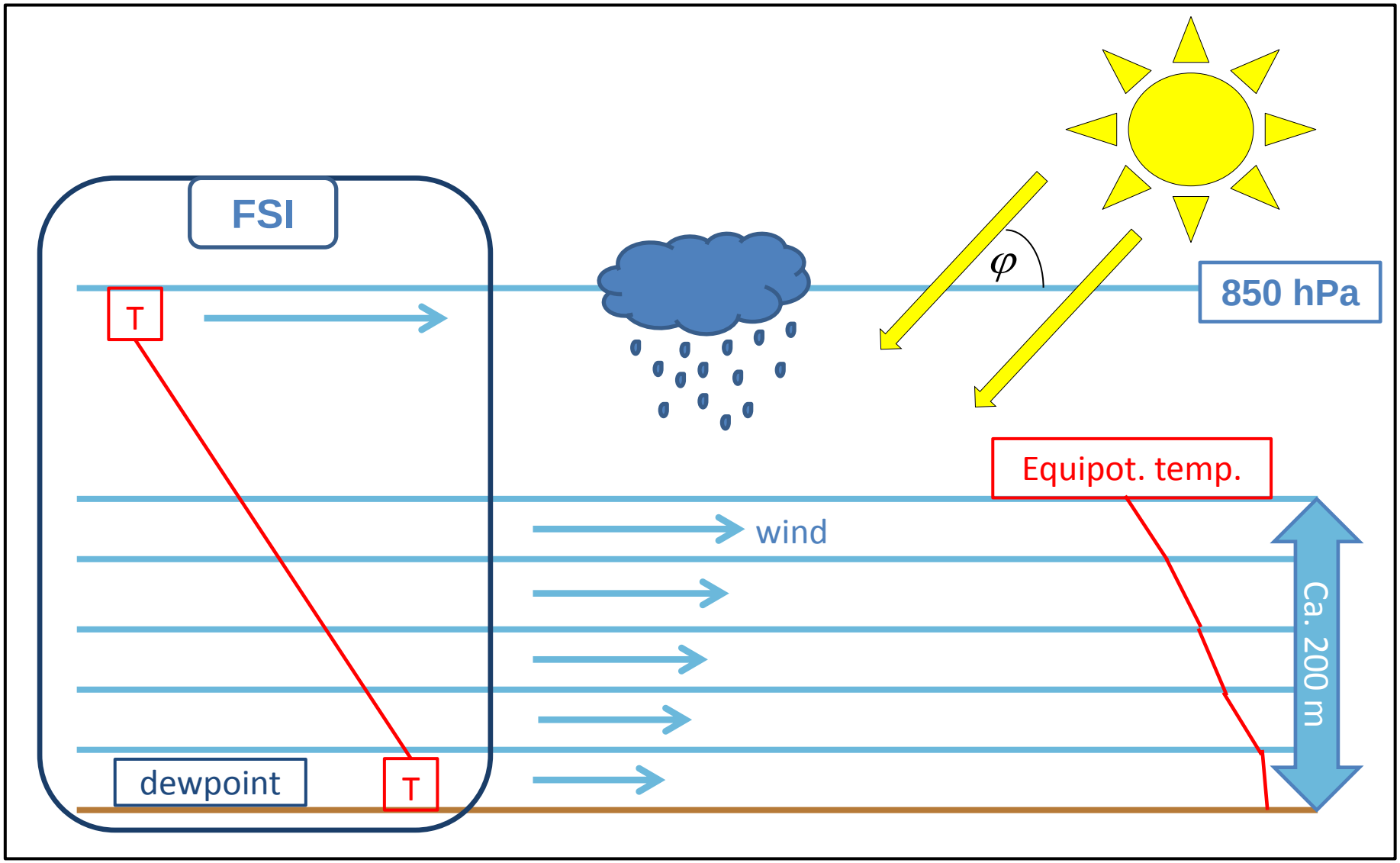
$\lambda > 0$: LASSO-Parameter

- Predictors → LASSO → select parameters
- Many variables can be tested
- Cross validation

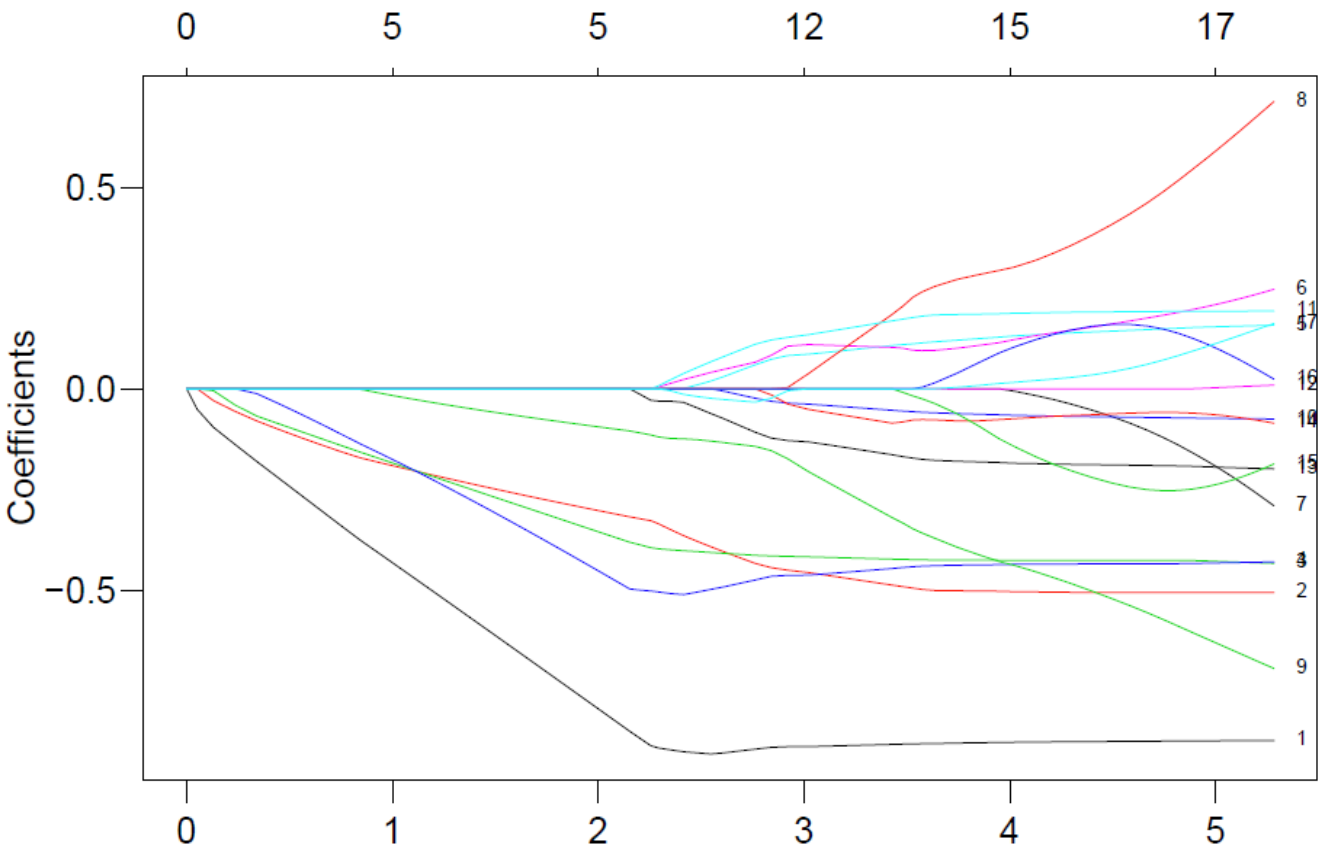
Choice of Predictors



Choice of Predictors



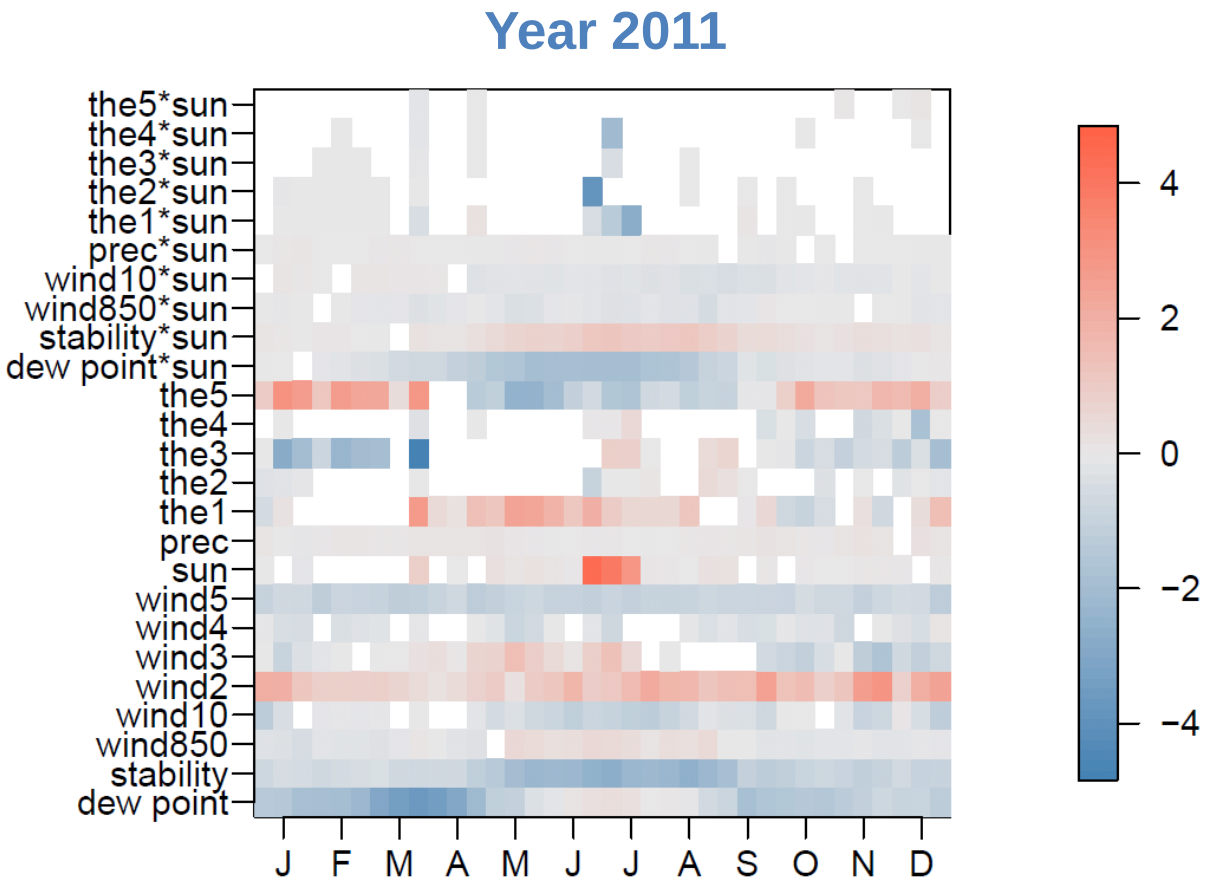
LASSO Paths – November 2011



(1) Dewpoint spread
(2) Stability
(3) Wind 850 hPa
(4) Wind 10 m
(9) Theta 5

LASSO-Parameter λ

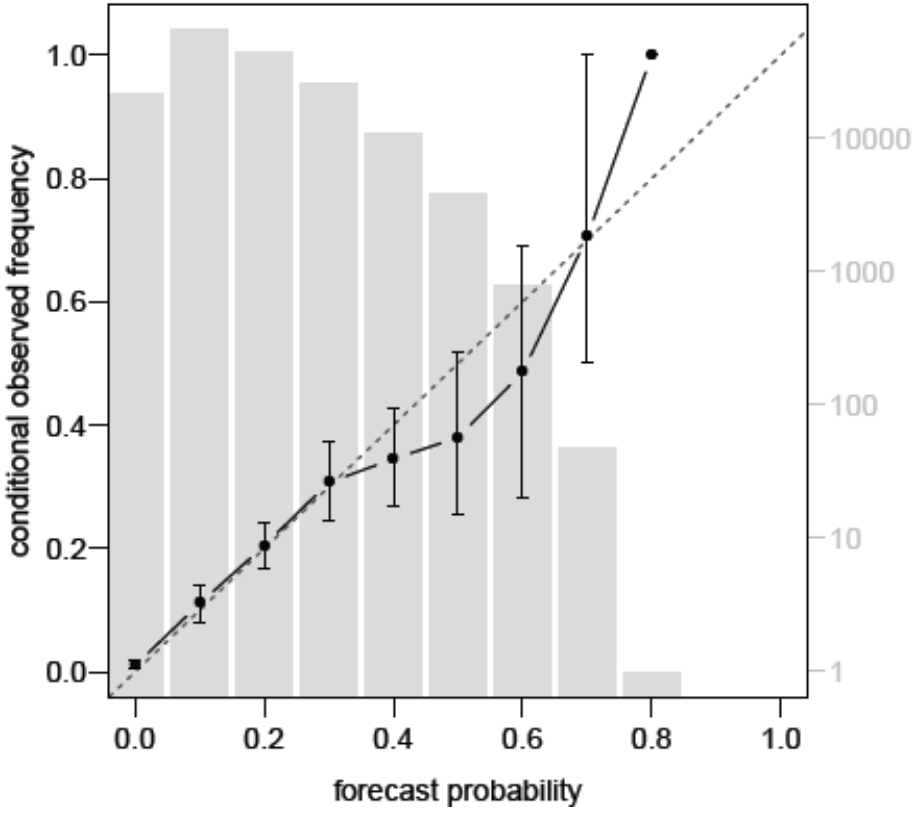
Cross validation LASSO-GLM



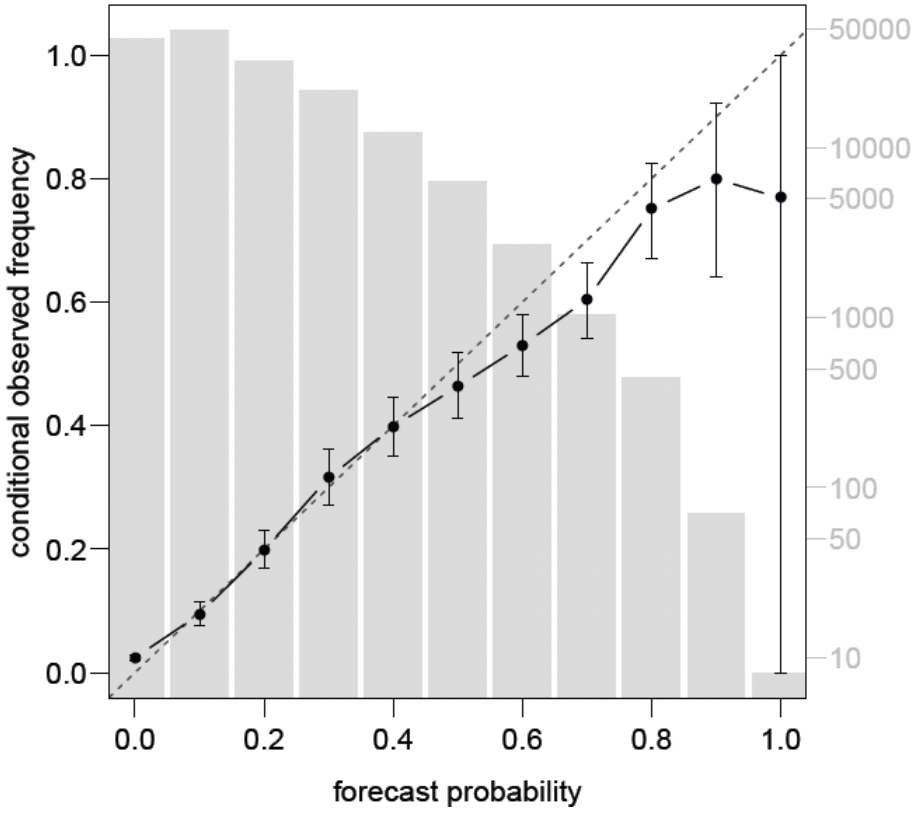
- penalized coefficients from LASSO for each verification period
- influence of parameters on fog formation changes over the year
- sun and interaction with other variables do not have much influence

Reliabilitydiagram – November 2011

FSI (COSMO-DE)

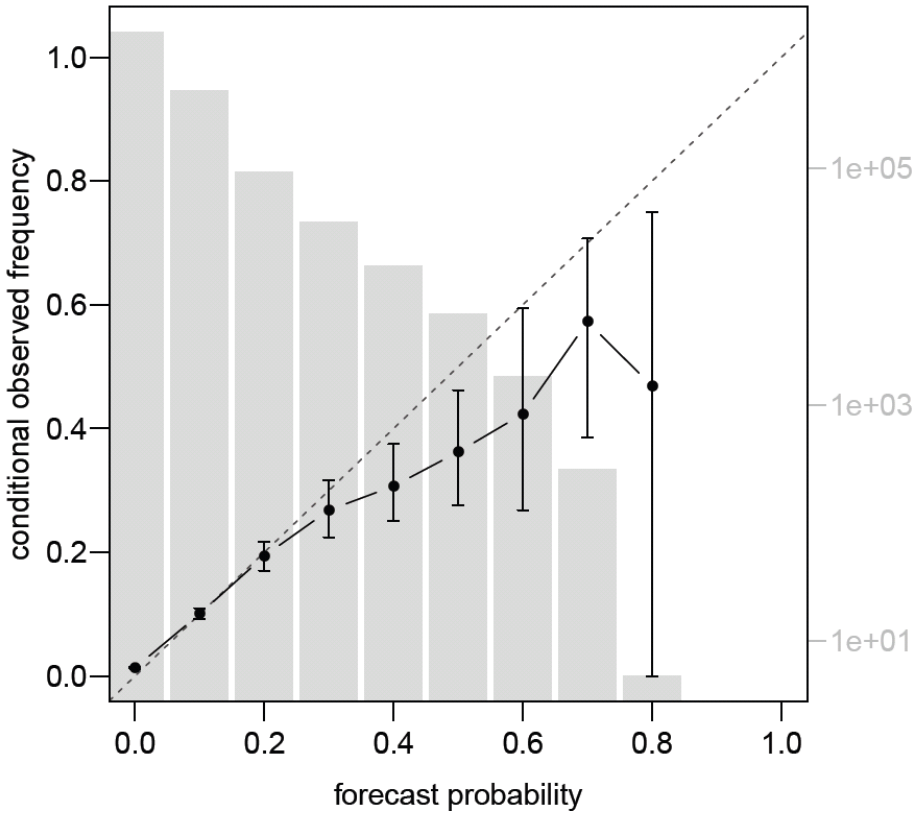


FOGCAST (COSMO-DE)

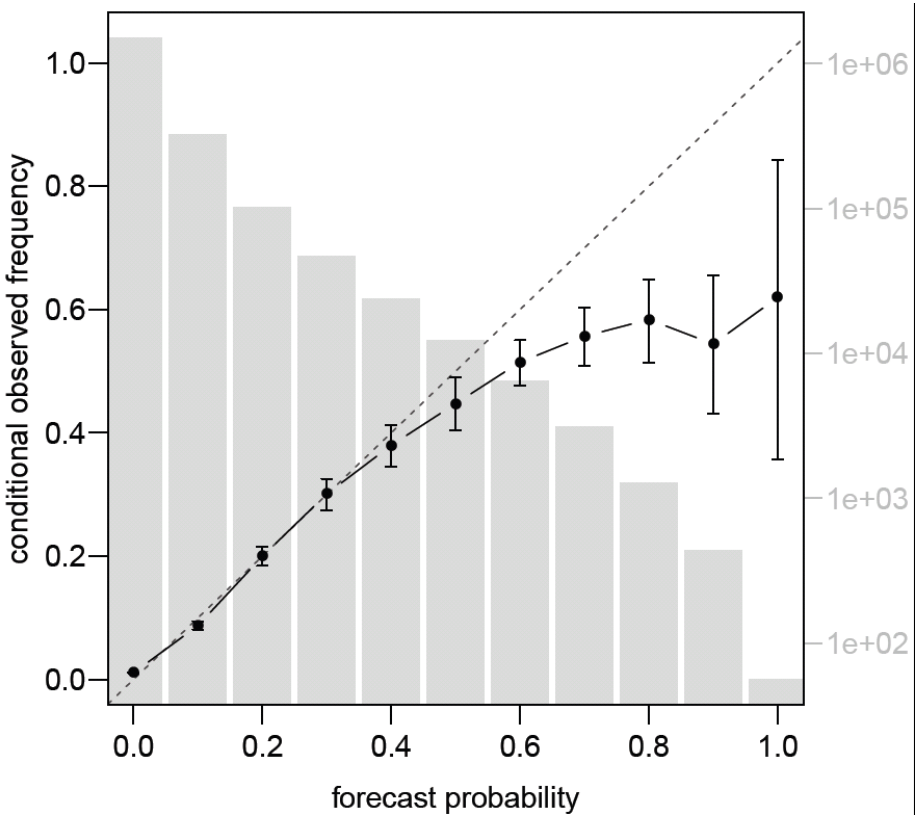


Reliabilitydiagram – Year 2011

FSI (COSMO-DE)



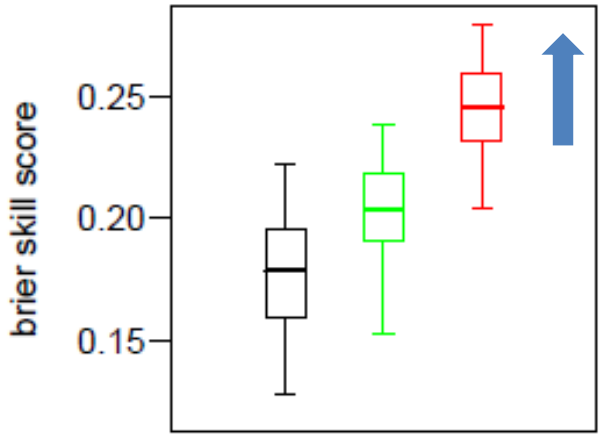
FOGCAST (COSMO-DE)

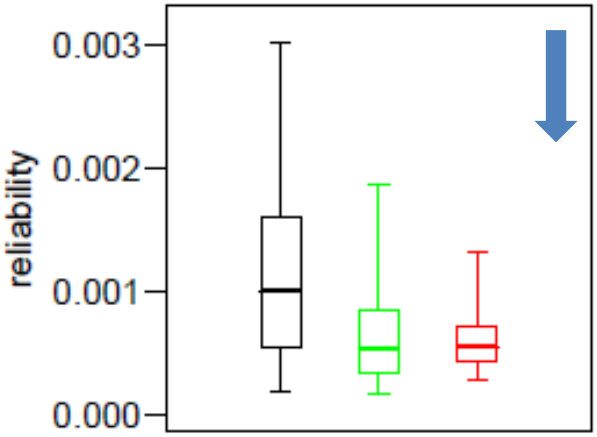


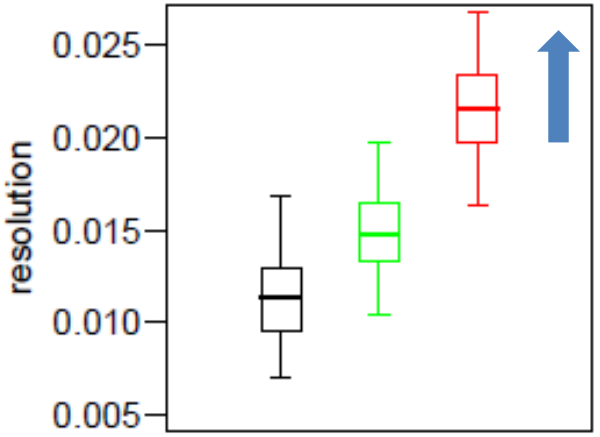
Brier Score

$$BS = \frac{1}{n}\sum_{i=1}^{I} N_i\left(y_i - \bar{o}_i\right)^2 - \frac{1}{n}\sum_{i=1}^{I} N_i\left(\bar{o}_i - \bar{o}\right)^2 + \bar{o}\left(1-\bar{o}\right)$$

Reliability Resolution Uncertainty





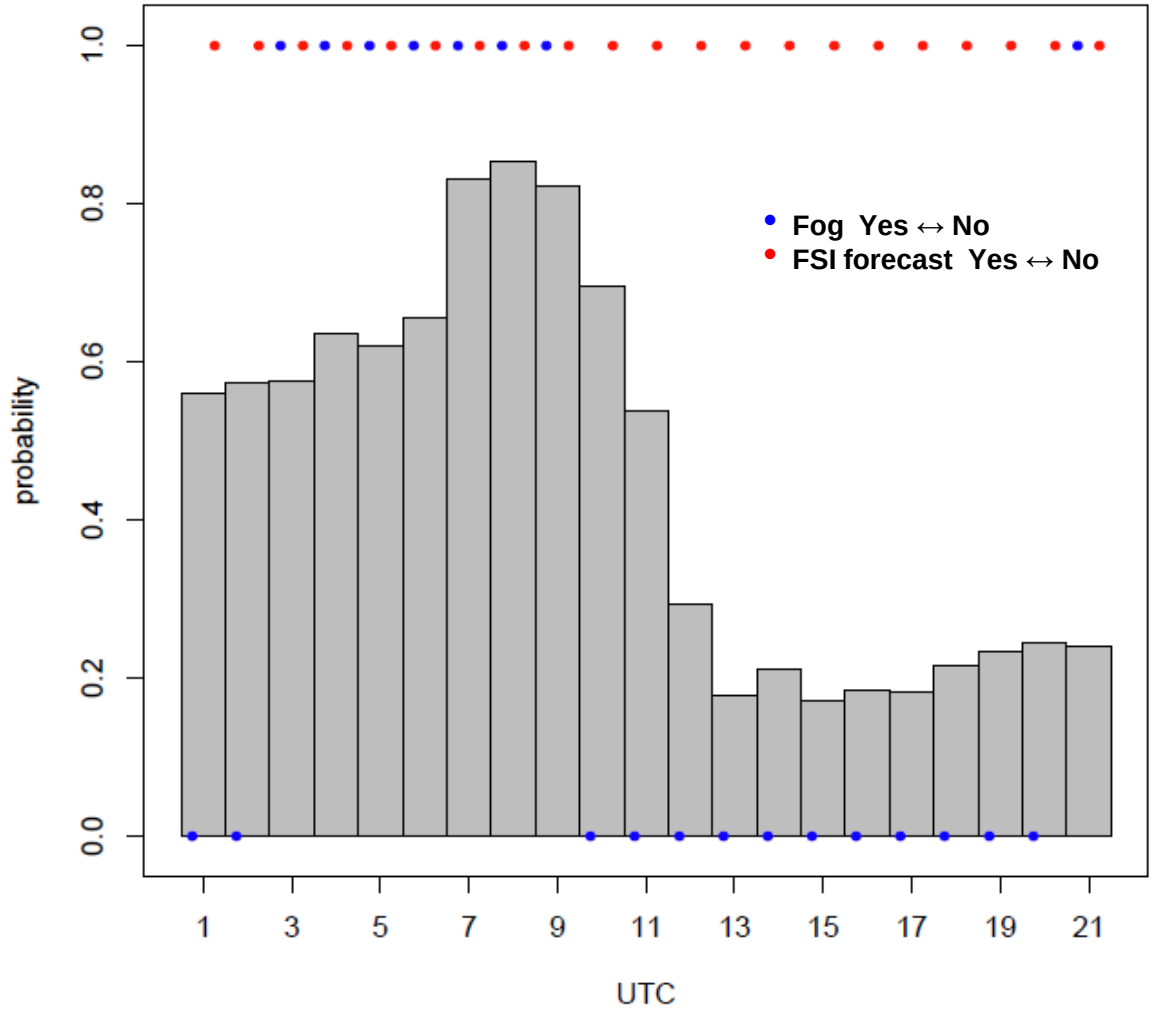


Reference: climatology at each station over the year 2011

FSI
Components of FSI
FOGCAST

Comparison of FSI and FOGCAST

14.11.2011 Munich-City



Conclusions & Outlook

- FOGCAST – a probabilistic fog forecast based on COSMO-DE forecasts
    - Quantification of **forecast uncertainty**

- The FSI components contain the largest skill (BSS ~20%)
- With LASSO-GLM: additional covariates show clear improvement of fog forecast (BSS ~25%)

- FOGCAST as **testbed**
    - Identification of skillful predictors

- Next step
    - Test influence of vertical resolution
    - Test with different turbulence scheme and microphysics

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