

Analysis of Media Precipitation Forecasts

Dr. Kenric P. Nelson
Photrek, LLC
May, 2020

Introduction

- Harold Brooks provided a dataset of precipitation forecasts from two TV stations, similar to the data in the paper: H. E. Brooks, A. Witt, and M. D. Eilts, “Verification of Public Weather Forecasts Available via the Media,” Bull. Am. Meteorol. Soc., 78, 10, 1997.
- The forecasts provide a probability of rain for one to seven days in advance of the event or outcome day.
- In this presentation the first station forecasts are analyzed, which has 321 outcome days.
- The analysis computes the “average” probability forecast, which is the generalized mean of the forecasts for each event (rain/no rain).
- This average forecast, called the accuracy, is compared with the outcome forecast which sets an ideal forecasts given the available features for the forecast.
- The accuracy of the forecasts is bounded by measures of decisiveness and robustness, which provide an indication of the variability of the forecasts.

Precipitation Forecasts Data

TV Station 1

Photrek

Number of Forecasts

	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99
D1	162	1	10	15	37	36	16	12	18	4	4	0	2	0	4
D2	169	0	4	20	32	42	25	10	14	4	1	0	0	0	0
D3	176	0	1	13	53	32	21	16	6	2	0	0	0	0	1
D4	172	0	1	16	51	37	29	13	2	0	0	0	0	0	0
D5	169	0	2	10	78	39	15	7	1	0	0	0	0	0	0
D6	181	0	0	13	71	43	9	3	1	0	0	0	0	0	0
D7	140	0	0	16	117	40	8	0	0	0	0	0	0	0	0

Fraction of Rain Days

	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99
D1	$\frac{5}{162}$	0.01	0.01	$\frac{2}{15}$	$\frac{7}{37}$	$\frac{13}{36}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{11}{18}$	0.99	0.99	NA	$\frac{1}{2}$	NA	$\frac{3}{4}$
D2	$\frac{10}{169}$	NA	$\frac{1}{4}$	$\frac{3}{10}$	$\frac{5}{32}$	$\frac{2}{7}$	$\frac{12}{25}$	$\frac{3}{5}$	$\frac{11}{14}$	$\frac{3}{4}$	0.99	NA	NA	NA	NA
D3	$\frac{5}{44}$	NA	0.01	0.01	$\frac{11}{53}$	$\frac{13}{32}$	$\frac{11}{21}$	$\frac{3}{8}$	$\frac{5}{6}$	0.01	NA	NA	NA	NA	0.99
D4	$\frac{5}{43}$	NA	0.01	$\frac{1}{8}$	$\frac{14}{51}$	$\frac{11}{37}$	$\frac{16}{29}$	$\frac{3}{13}$	$\frac{1}{2}$	NA	NA	NA	NA	NA	NA
D5	$\frac{19}{169}$	NA	0.01	$\frac{1}{5}$	$\frac{10}{39}$	$\frac{16}{39}$	$\frac{7}{15}$	$\frac{2}{7}$	0.99	NA	NA	NA	NA	NA	NA
D6	$\frac{24}{181}$	NA	NA	$\frac{2}{13}$	$\frac{21}{71}$	$\frac{14}{43}$	$\frac{4}{9}$	$\frac{1}{3}$	0.99	NA	NA	NA	NA	NA	NA
D7	$\frac{1}{5}$	NA	NA	$\frac{1}{8}$	$\frac{22}{117}$	$\frac{13}{40}$	$\frac{1}{4}$	NA	NA	NA	NA	NA	NA	NA	NA

Fraction of Non-Rain Days

	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99
D1	$\frac{1}{4}$	NA	$\frac{1}{2}$	NA	0.01	0.01	$\frac{7}{18}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{23}{36}$	$\frac{30}{37}$	$\frac{13}{15}$	0.99	0.99	157
D2	NA	NA	NA	NA	0.01	$\frac{1}{4}$	$\frac{3}{14}$	$\frac{2}{5}$	$\frac{13}{25}$	$\frac{5}{7}$	$\frac{27}{32}$	$\frac{7}{10}$	$\frac{3}{4}$	NA	159
D3	0.01	NA	NA	NA	NA	0.99	$\frac{1}{6}$	$\frac{5}{8}$	$\frac{10}{19}$	$\frac{19}{42}$	0.99	0.99	NA	39	44
D4	NA	NA	NA	NA	NA	NA	$\frac{1}{2}$	$\frac{10}{13}$	$\frac{13}{26}$	$\frac{26}{37}$	$\frac{7}{51}$	$\frac{8}{51}$	0.99	NA	38
D5	NA	NA	NA	NA	NA	NA	$\frac{1}{7}$	$\frac{5}{15}$	$\frac{8}{39}$	$\frac{23}{39}$	$\frac{29}{39}$	$\frac{4}{5}$	0.99	NA	150
D6	NA	NA	NA	NA	NA	NA	$\frac{1}{3}$	$\frac{5}{9}$	$\frac{29}{43}$	$\frac{50}{71}$	$\frac{11}{13}$	NA	NA	169	157
D7	NA	NA	NA	NA	NA	NA	NA	$\frac{3}{4}$	$\frac{27}{40}$	$\frac{95}{117}$	$\frac{7}{8}$	NA	NA	4	5

Precipitation Forecasts Data

TV Station 2

Photrek

Number of Forecasts

	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99
D1	170	0	9	0	58	28	24	9	10	6	5	0	1	0	1
D2	182	0	8	0	67	28	26	5	5	0	0	0	0	0	0
D3	207	0	7	0	60	29	15	1	2	0	0	0	0	0	0
D4	193	0	8	0	88	21	10	1	0	0	0	0	0	0	0
D5	202	0	5	0	82	24	8	0	0	0	0	0	0	0	0
D6	212	0	3	0	92	12	2	0	0	0	0	0	0	0	0
D7	233	0	1	0	80	7	0	0	0	0	0	0	0	0	0

Fraction of Rain Days

	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99
D1	$\frac{7}{170}$	NA	0.01	NA	$\frac{6}{29}$	$\frac{3}{7}$	$\frac{3}{8}$	$\frac{7}{9}$	$\frac{9}{10}$	$\frac{5}{6}$	$\frac{4}{5}$	NA	0.99	NA	0.99
D2	$\frac{8}{91}$	NA	0.01	NA	$\frac{19}{67}$	$\frac{9}{28}$	$\frac{15}{26}$	$\frac{4}{5}$	$\frac{4}{5}$	NA	NA	NA	NA	NA	NA
D3	$\frac{25}{207}$	NA	$\frac{3}{7}$	NA	$\frac{7}{30}$	$\frac{18}{29}$	$\frac{1}{3}$	0.01	0.99	NA	NA	NA	NA	NA	NA
D4	$\frac{22}{193}$	NA	$\frac{3}{8}$	NA	$\frac{7}{22}$	$\frac{1}{3}$	$\frac{7}{10}$	0.01	NA	NA	NA	NA	NA	NA	NA
D5	$\frac{29}{202}$	NA	0.01	NA	$\frac{27}{82}$	$\frac{1}{3}$	$\frac{3}{8}$	NA	NA	NA	NA	NA	NA	NA	NA
D6	$\frac{19}{106}$	NA	$\frac{1}{3}$	NA	$\frac{21}{92}$	$\frac{1}{2}$	$\frac{1}{2}$	NA	NA	NA	NA	NA	NA	NA	NA
D7	$\frac{47}{233}$	NA	0.01	NA	$\frac{19}{80}$	$\frac{1}{7}$	NA	NA	NA	NA	NA	NA	NA	NA	NA

Fraction of Non-Rain Days

	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99
D1	0.01	NA	0.01	NA	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{10}$	$\frac{2}{9}$	$\frac{5}{8}$	$\frac{4}{7}$	$\frac{23}{29}$	NA	0.99	NA	$\frac{163}{170}$
D2	NA	NA	NA	NA	NA	NA	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{11}{26}$	$\frac{19}{28}$	$\frac{48}{67}$	NA	0.99	NA	$\frac{83}{91}$
D3	NA	NA	NA	NA	NA	NA	0.01	0.99	$\frac{2}{3}$	$\frac{11}{29}$	$\frac{23}{30}$	NA	$\frac{4}{7}$	NA	$\frac{182}{207}$
D4	NA	NA	NA	NA	NA	NA	NA	0.99	$\frac{3}{10}$	$\frac{2}{3}$	$\frac{15}{22}$	NA	$\frac{5}{8}$	NA	$\frac{171}{193}$
D5	NA	NA	NA	NA	NA	NA	NA	NA	$\frac{5}{8}$	$\frac{2}{3}$	$\frac{55}{82}$	NA	0.99	NA	$\frac{173}{202}$
D6	NA	NA	NA	NA	NA	NA	NA	NA	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{71}{92}$	NA	$\frac{2}{3}$	NA	$\frac{87}{106}$
D7	NA	NA	NA	NA	NA	NA	NA	NA	$\frac{6}{7}$	$\frac{61}{80}$	NA	0.99	NA	$\frac{186}{233}$	

Precipitation Forecast Data

Baseline Climatology

Photrek

Forecasts per Percentile for Baseline

	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99
B1	NA	NA	NA	321	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B2	NA	NA	NA	NA	321	NA									

Fraction of Rain Days for Baseline

	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99
B1	NA	NA	NA	$\frac{67}{321}$	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B2	NA	NA	NA	NA	$\frac{67}{321}$	NA									

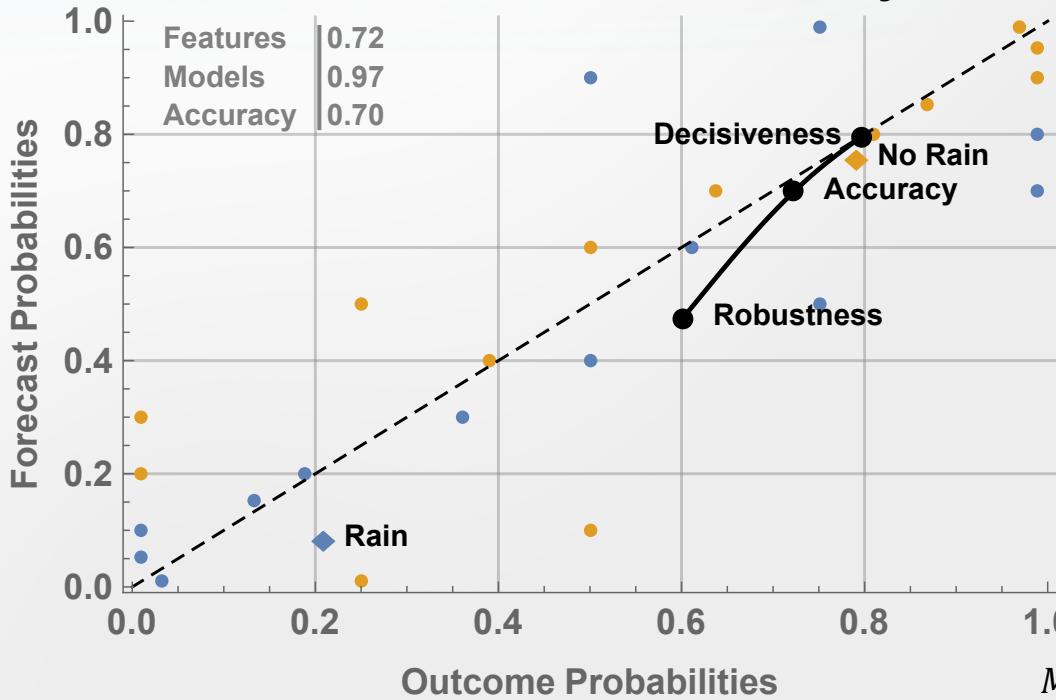
Fraction of non-Rain Days for Baseline

	1	5	10	15	20	30	40	50	60	70	80	85	90	95	99
B1	NA	$\frac{254}{321}$	NA	NA	NA										
B2	NA	$\frac{254}{321}$	NA	NA	NA	NA									

Forecast Assessment

Photrek

Forecasts vs. Outcomes – 1 Day Out



- Generalized Mean used to assess accuracy of forecasts as a function of risk bias
- Decisiveness ($r = 1$) – Arithmetic Mean
- Accuracy ($r = 0$) – Geometric Mean
- Robustness ($r = -2/3$) – $-2/3^{\text{rds}}$ Mean

- Small circles are raw data of Forecasted Probability versus Outcome Probability (or fraction)
- Diamonds are the overall classification versus the percentage of rain/not rain events
- Forecast Accuracy (0.70) is due to outcome from features (0.72) times the model divergence (0.97)

$$M_{r,w}(\mathbf{p}^{f,o}) = \begin{cases} \left(\sum_{i=1}^{N_f} w_i (p_i^{f,o})^r \right)^{\frac{1}{r}} & r \neq 0 \\ \prod_{i=1}^{N_f} (p_i^{f,o})^{w_i} & r = 0 \end{cases}$$

\mathbf{p}^f – forecasts; \mathbf{p}^o – outcomes; $w_i = p_i^0 / \sum_{i=1}^{N_f} p_i^0$
 r – risk bias; N_f – number of forecast bins

Calculation of Probability Accuracy *Photrek*

$$M_{r,w}(\mathbf{p}^{f,o}) = \prod_{i=1}^{N_f} (p_i^{f,o})^{w_i}$$

\mathbf{p}^f – forecasts; \mathbf{p}^o – outcomes; $w_i = p_i^0 / \sum_{i=1}^{N_f} p_i^0$

$r=0$ (no risk bias); N_f – number of forecast bins

$$M_0(\mathbf{p}^f) = 0.01^{\frac{5}{321}} 0.05^{\frac{0.01}{321}} 0.1^{\frac{0.01}{321}} 0.15^{\frac{2}{321}} 0.2^{\frac{7}{321}} 0.3^{\frac{13}{321}} 0.4^{\frac{8}{321}} 0.5^{\frac{9}{321}} 0.6^{\frac{11}{321}} 0.7^{\frac{4}{321}} 0.8^{\frac{4}{321}} 0.85^{\frac{0}{321}} 0.9^{\frac{1}{321}} 0.95^{\frac{0}{321}} 0.99^{\frac{3}{321}}$$

Rain

$$* 0.01^{\frac{1}{321}} 0.05^{\frac{0}{321}} 0.1^{\frac{1}{321}} 0.15^{\frac{0}{321}} 0.2^{\frac{0}{321}} 0.3^{\frac{0}{321}} 0.4^{\frac{7}{321}} 0.5^{\frac{3}{321}} 0.6^{\frac{8}{321}} 0.7^{\frac{23}{321}} 0.8^{\frac{30}{321}} 0.85^{\frac{13}{321}} 0.9^{\frac{.99}{321}} 0.95^{\frac{.99}{321}} 0.99^{\frac{157}{321}}$$

non-Rain

$$= 0.70 \text{ Forecast Accuracy}$$

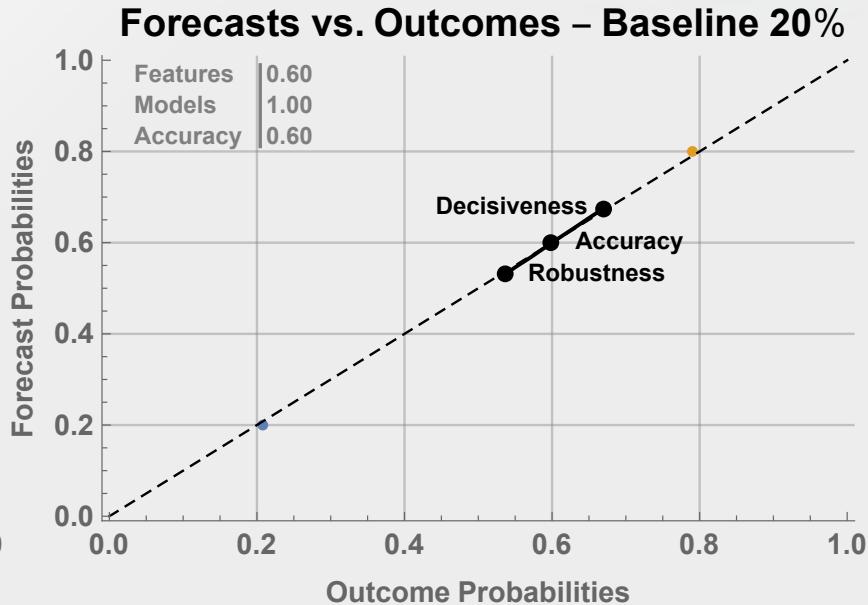
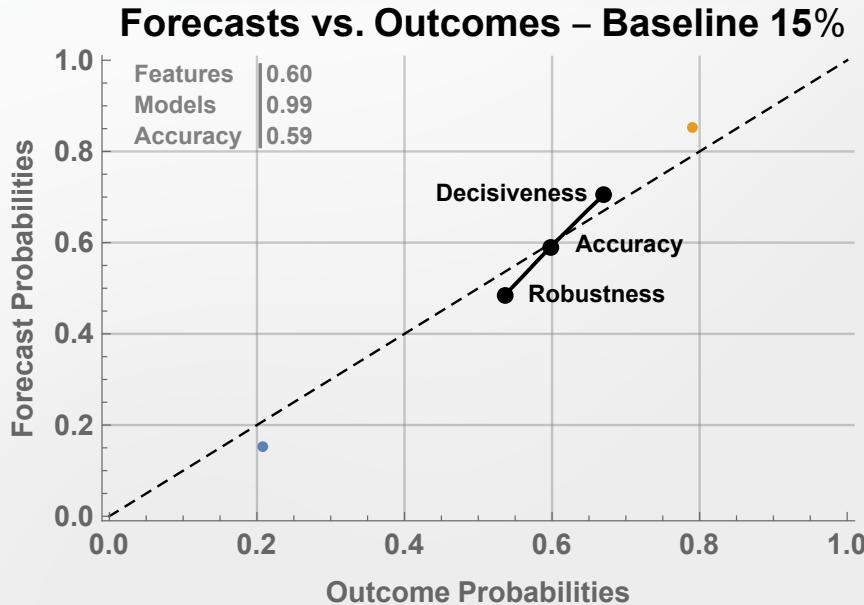
$$M_0(\mathbf{p}^o) = \left(\frac{5}{162} \frac{157}{162} \right)^{\frac{162}{321}} \left(- \right)^0 \left(0.01^{0.01} 0.99^{0.99} \right)^{\frac{1}{321}} \left(- \right)^0 \left(0.01^{0.01} 0.99^{0.99} \right)^{\frac{10}{321}} \left(\frac{2}{15} \frac{13}{15} \right)^{\frac{15}{321}} \left(\frac{7}{37} \frac{30}{37} \right)^{\frac{37}{321}} \left(\frac{13}{36} \frac{23}{36} \right)^{\frac{36}{321}}$$

$$* \left(\frac{8}{16} \frac{8}{16} \right)^{\frac{16}{321}} \left(\frac{9}{12} \frac{3}{12} \right)^{\frac{12}{321}} \left(\frac{11}{18} \frac{7}{18} \right)^{\frac{18}{321}} \left(0.99^{0.99} 0.01^{0.01} \right)^{\frac{4}{321}} \left(0.99^{0.99} 0.01^{0.01} \right)^{\frac{4}{321}} \left(\frac{1}{2} \frac{1}{2} \right)^{\frac{2}{321}} \left(\frac{3}{4} \frac{1}{4} \right)^{\frac{4}{321}}$$

= 0.72 Outcome Accuracy

Baseline Forecasts of 15% & 20%

Photrek



A baseline forecast of 20% eliminates the divergence

A baseline forecast of 15% out-performs the 3-7 Day Forecasts

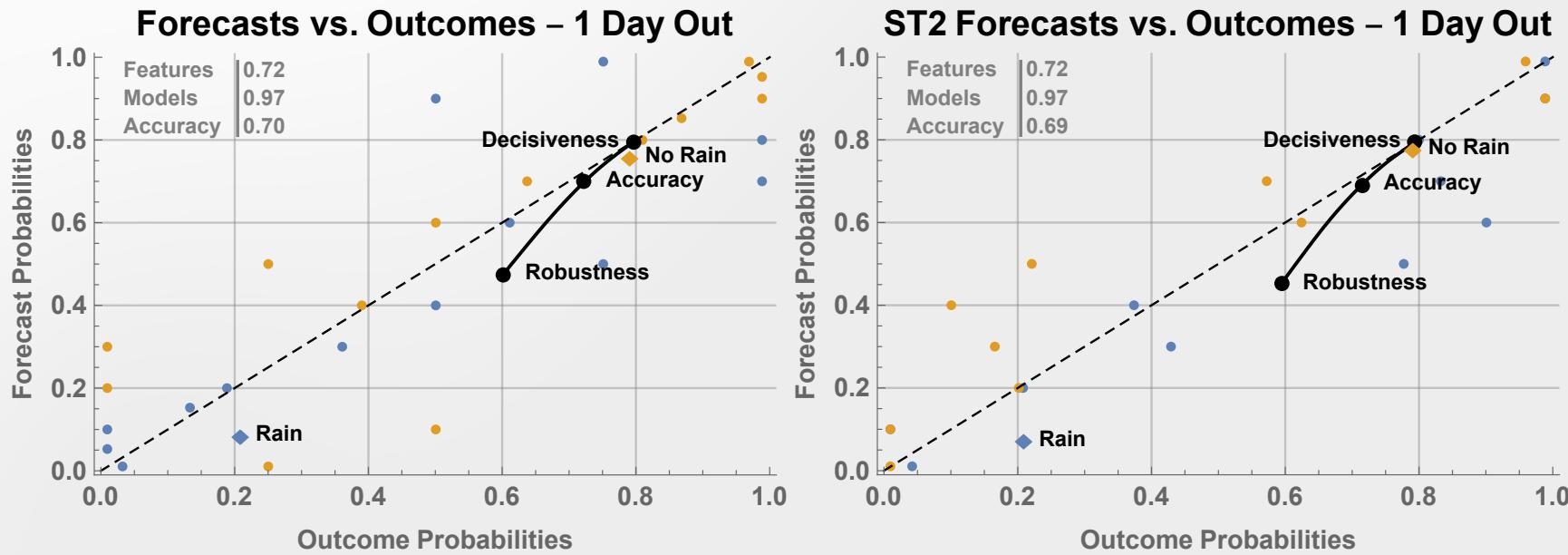
Conclusion: Multiday outlook forecasts could be improved by decreasing the deviation from the baseline, even if the baseline has some error.

Caveat: Improved binning may improve the forecasts performance

Compare Forecast Assessments

1 Day Out

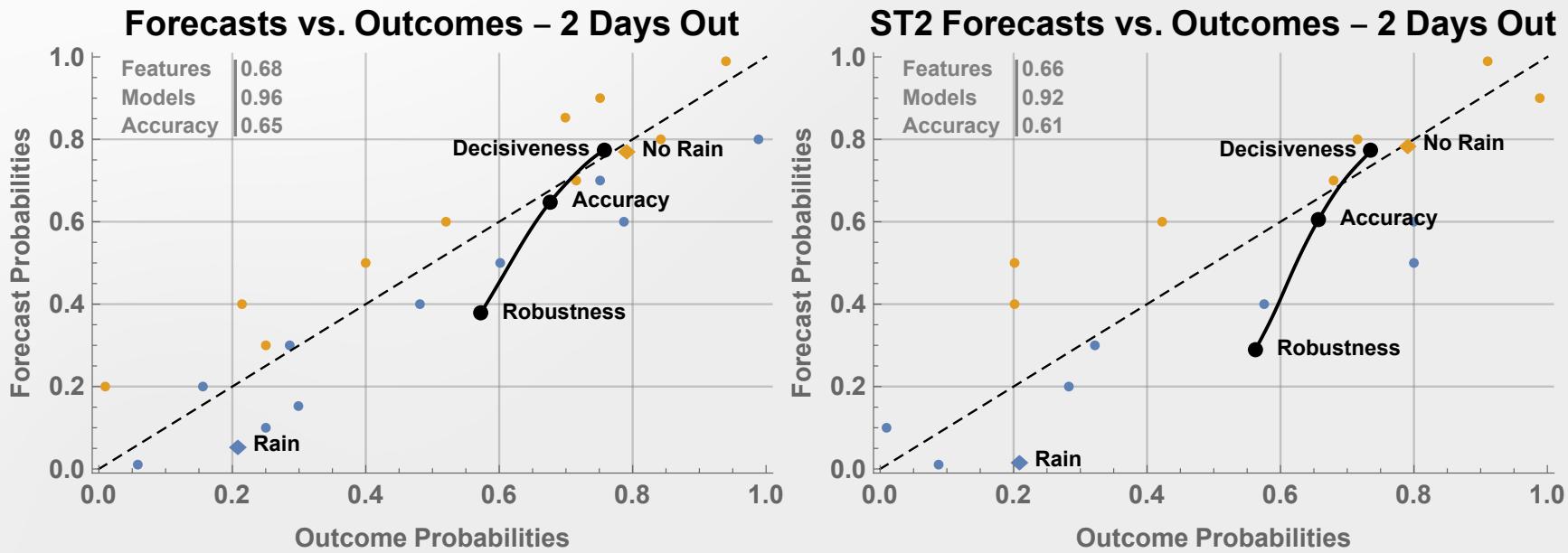
Photrek



Compare Forecast Assessments

2 Days Out

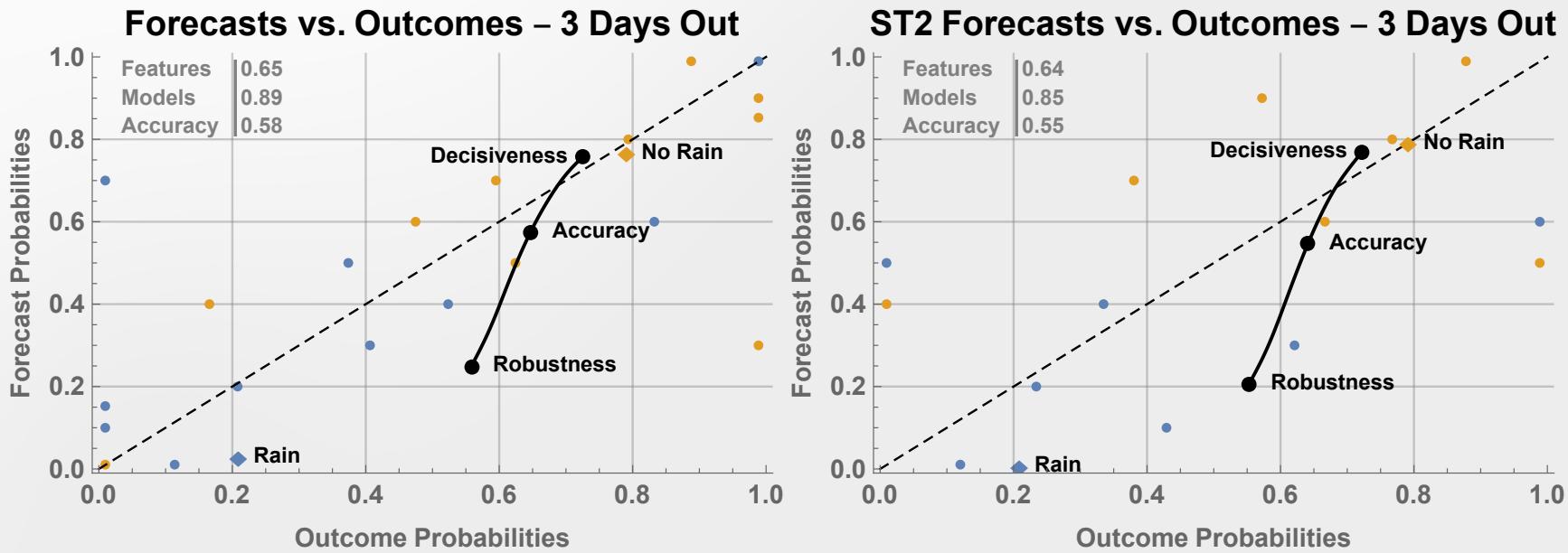
Photrek



Compare Forecast Assessments

3 Days Out

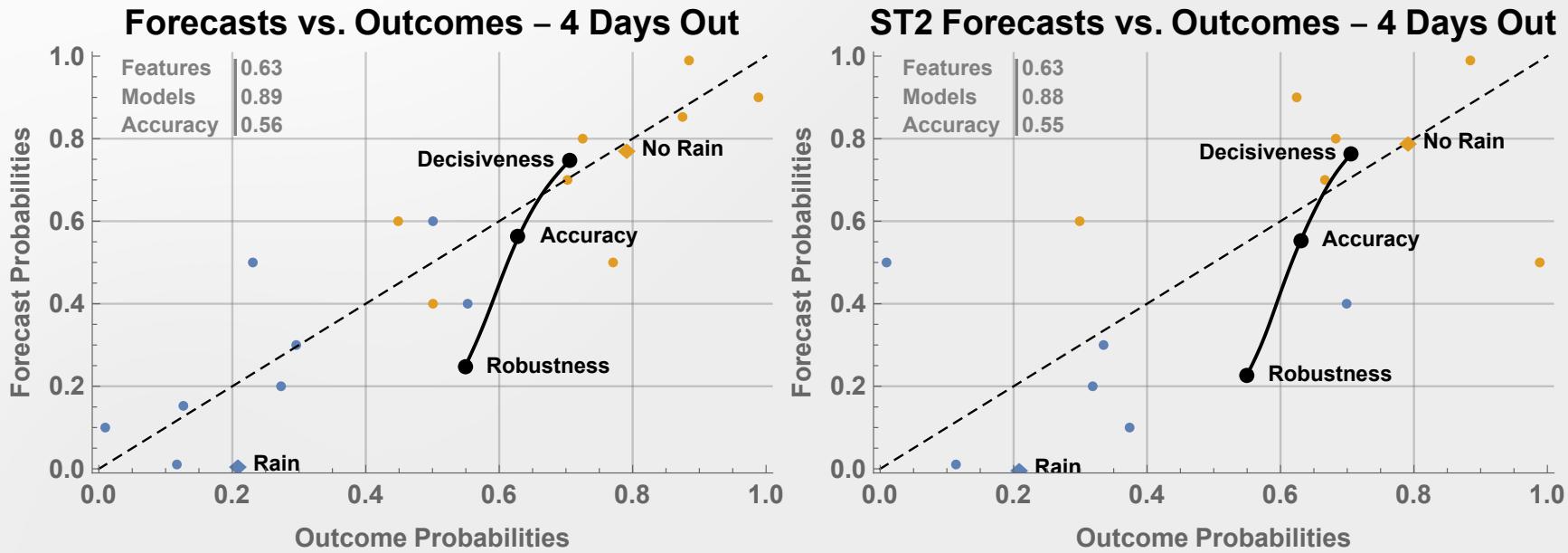
Photrek



Compare Forecast Assessments

4 Days Out

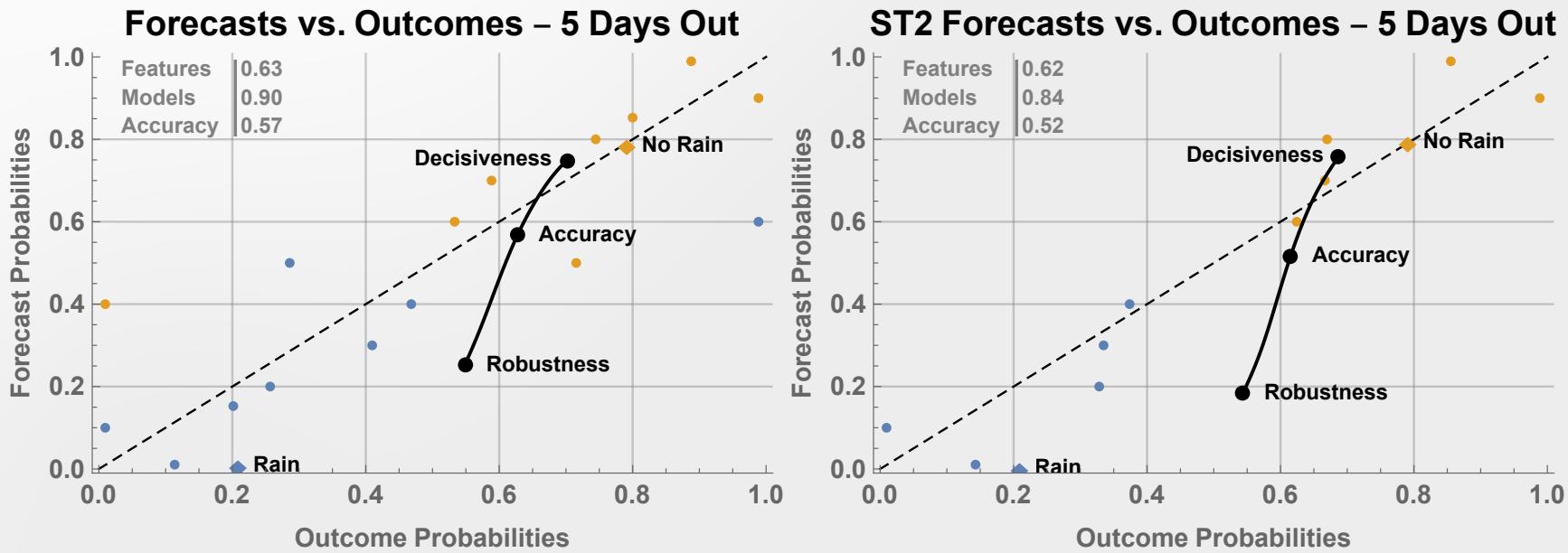
Photrek



Compare Forecast Assessments

5 Days Out

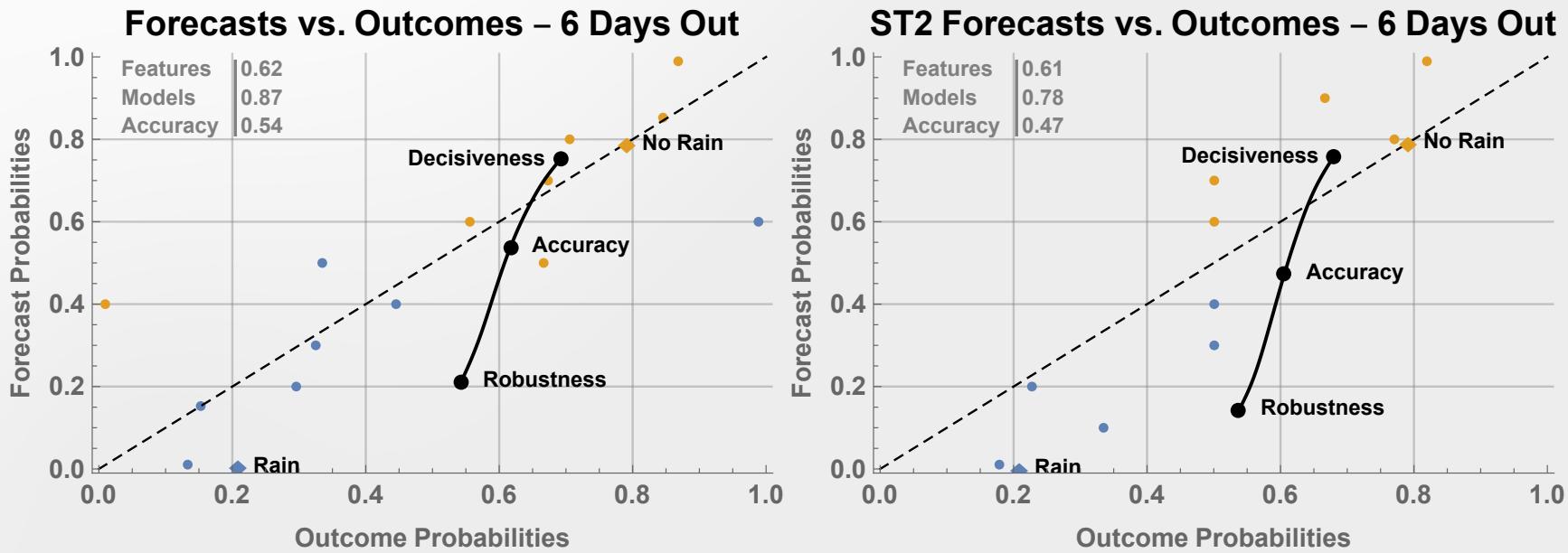
Photrek



Compare Forecast Assessments

6 Days Out

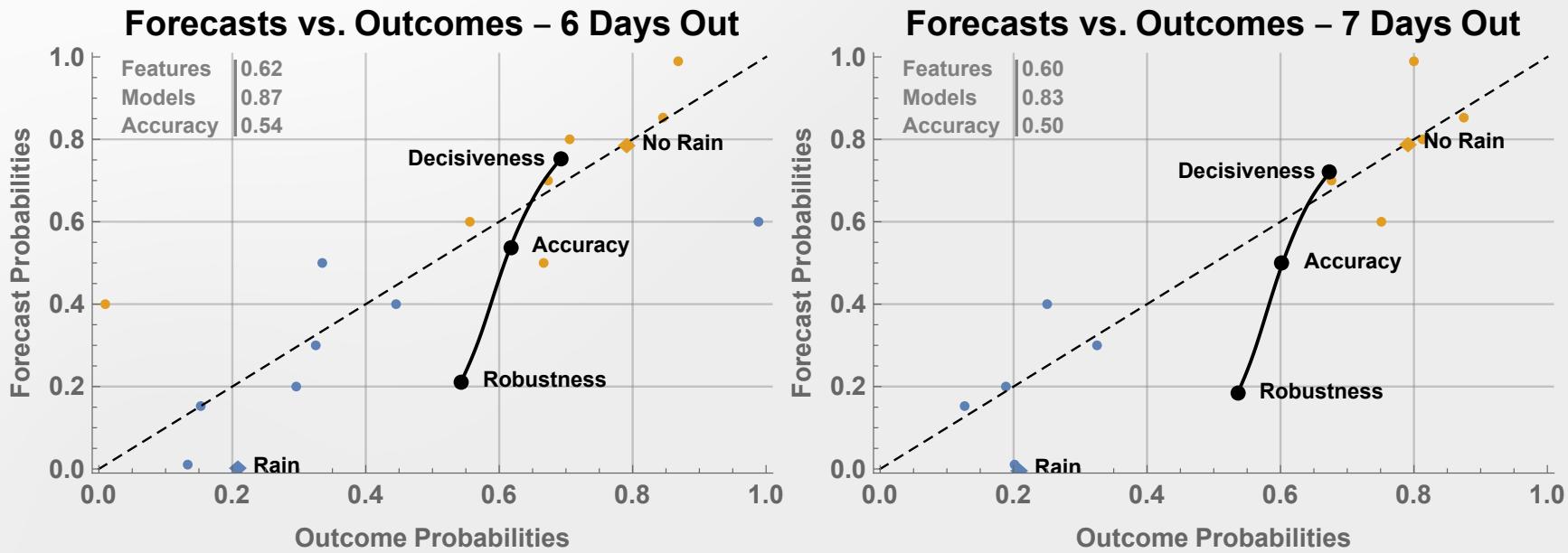
Photrek



Compare Forecast Assessments

6 Days Out

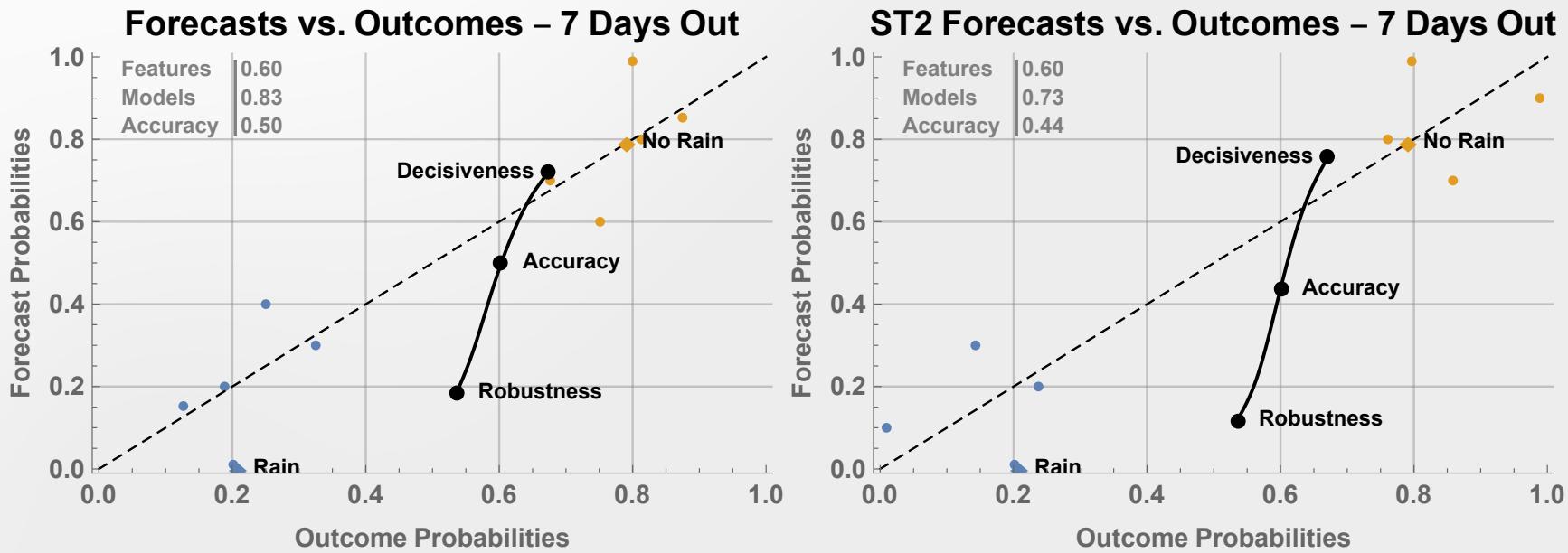
Photrek



Compare Forecast Assessments

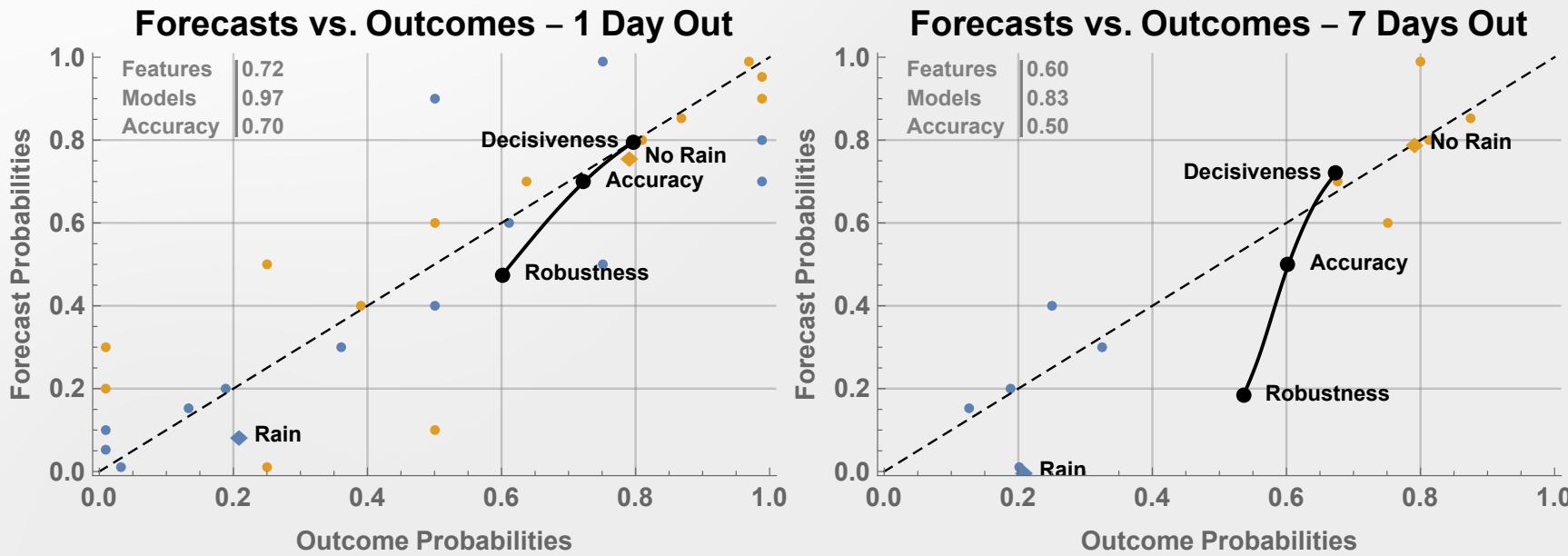
7 Days Out

Photrek



Forecast Assessments 1 & 7 Days Out

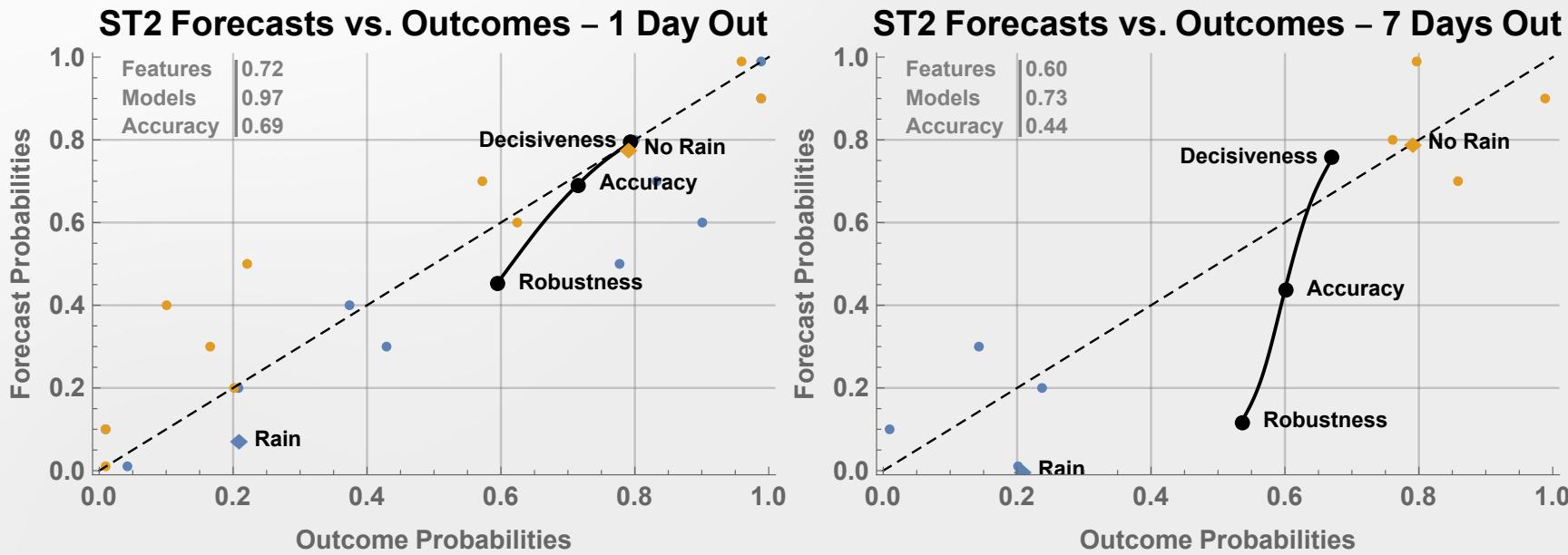
Photrek



- The outcome (or features) and divergence (or models) both improve from the 7 Day to the 1 Day Forecast
- This leads to an improvement in the accuracy of the forecast from 50% to 70%
- The robustness also improves from 19% to 47%

Forecast Assessments 1 & 7 Days Out

Photrek



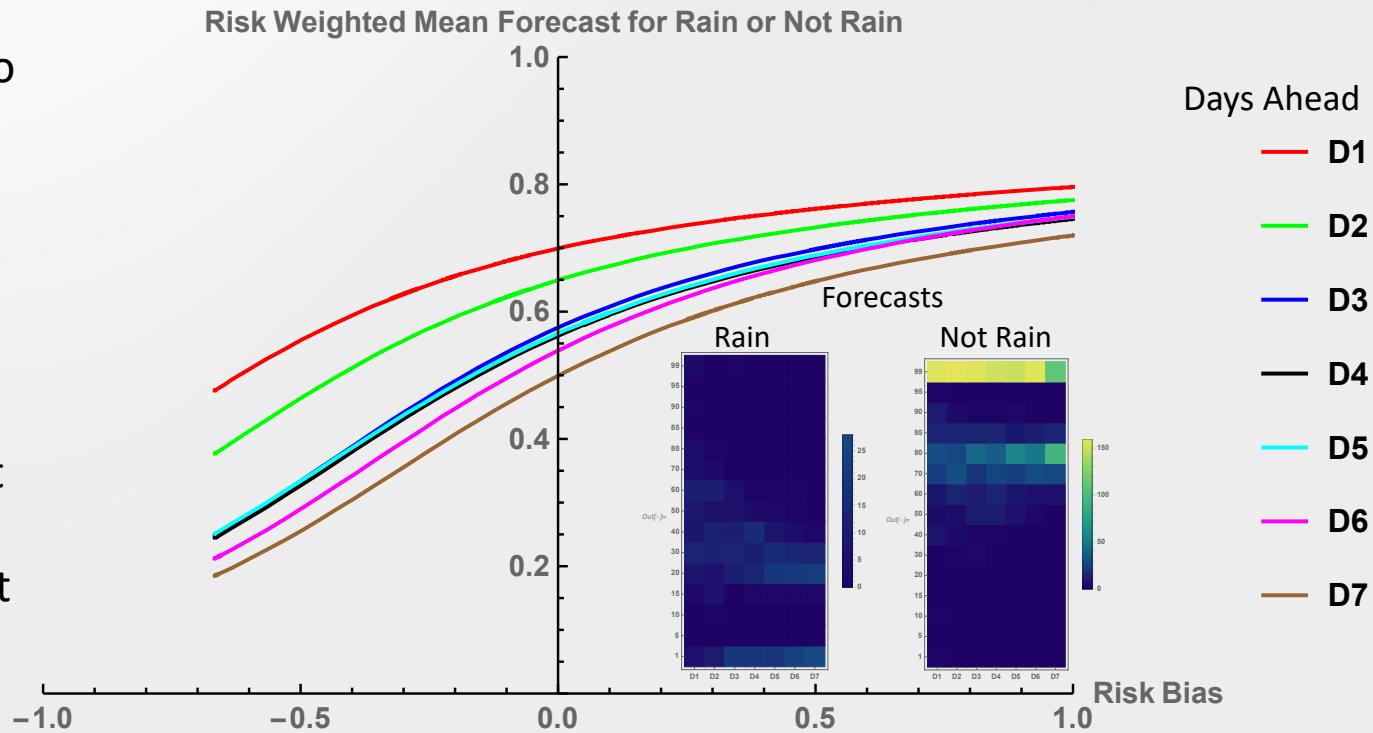
- The outcome (or features) and divergence (or models) both improve from the 7 Day to the 1 Day Forecast
- This leads to an improvement in the accuracy of the forecast from 50% to 70%
- The robustness also improves from 19% to 47%

Analysis of Media Rain Forecasts

Photrek

Forecast Performance

- Average forecast (no risk bias) ranges:
70% for 1 day out
50% for 7 days out
- Risk bias of 1 indicates that the prediction is correct
~ 78% for 1 day out
~ 68% for 7 days out
- Risk bias of $-2/3$ indicates that the ‘tail’ forecast ranges:
~ 48% 1 day out
~ 18% 7 days out

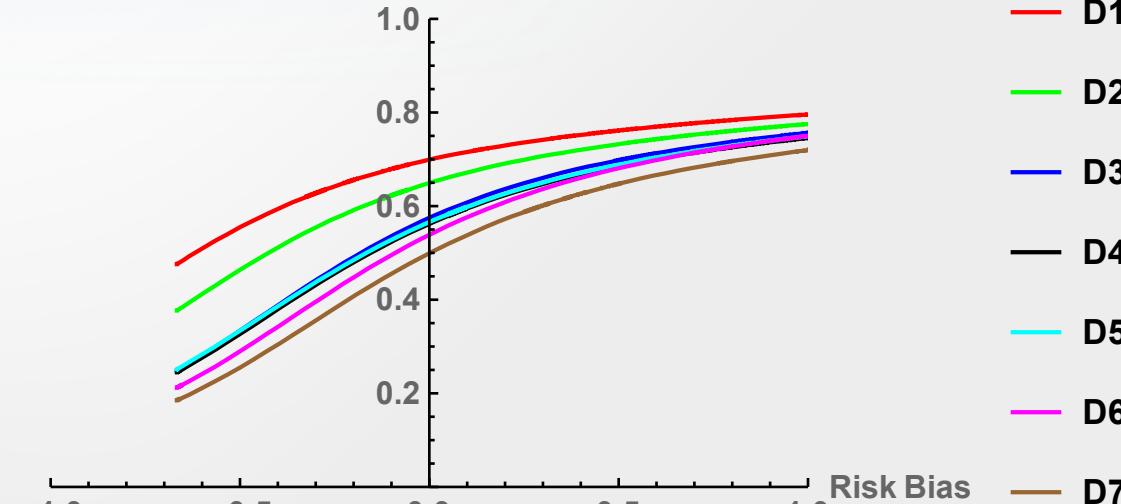


Data similar to H. E. Brooks, A. Witt, and M. D. Eilts,
“Verification of Public Weather Forecasts Available via the Media,”
Bull. Am. Meteorol. Soc., vol. 78, no. 10, 1997.

Comparison of Risk Profiles

Photrek

ST1 Risk Weighted Mean Forecast for Rain or Not Rain



ST2 Risk Weighted Mean Forecast for Rain or Not Rain

