Evaluation of Delta Forecasting MQO v5.1 for London

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  - Allowing for uncertainty

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  - (Different alarm thresholds)

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*air*TEXT forecasting system for London

Free air pollution, UV, pollen and temperature forecasts for Greater London

Currently providing free air quality alerts to more than 10 000 subscribers

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*air*TEXT forecasting system for London

Model performance (DELTA version 3.6)

- How well is *air*TEXT performing according to DELTA 3.6, using the 2013 dataset?

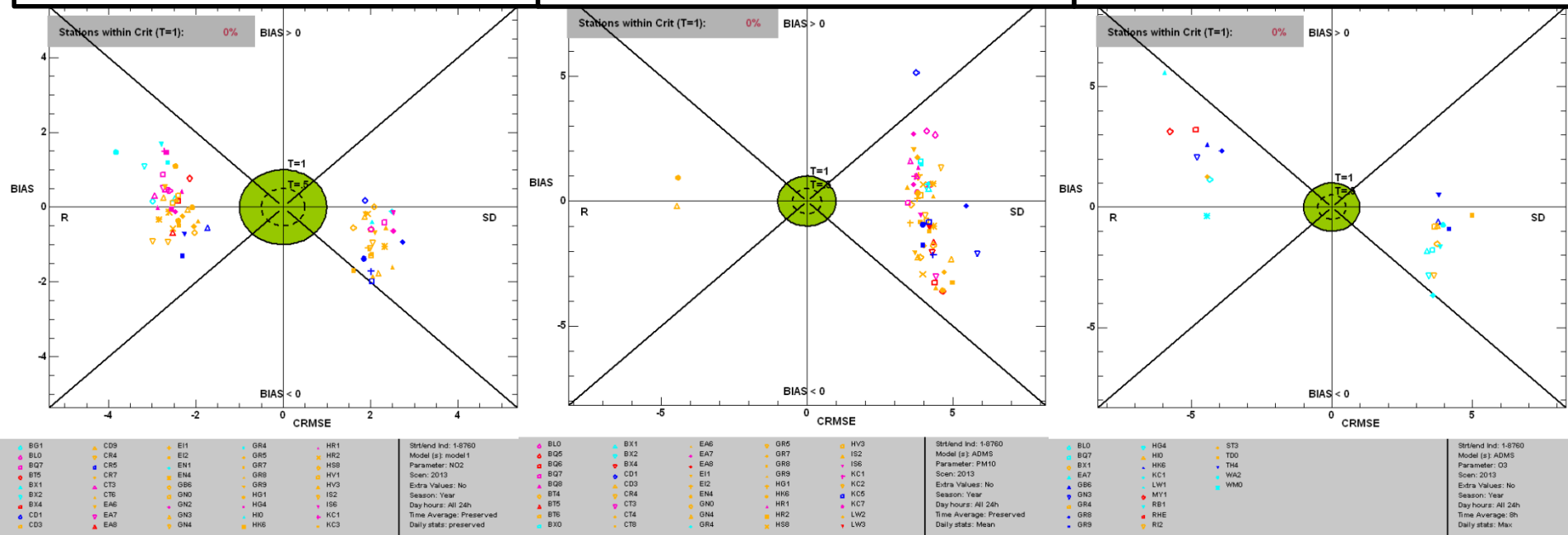| NO$_2$ (1-hour daily maximum)	PM$_{10}$ (24-hour daily average)	O$_3$ (8-hour daily maximum)

- Terribly!!!

Model performance (DELTA version 5.1)

- How well is *air*TEXT performing according to DELTA 5.1, using the 2013 dataset?

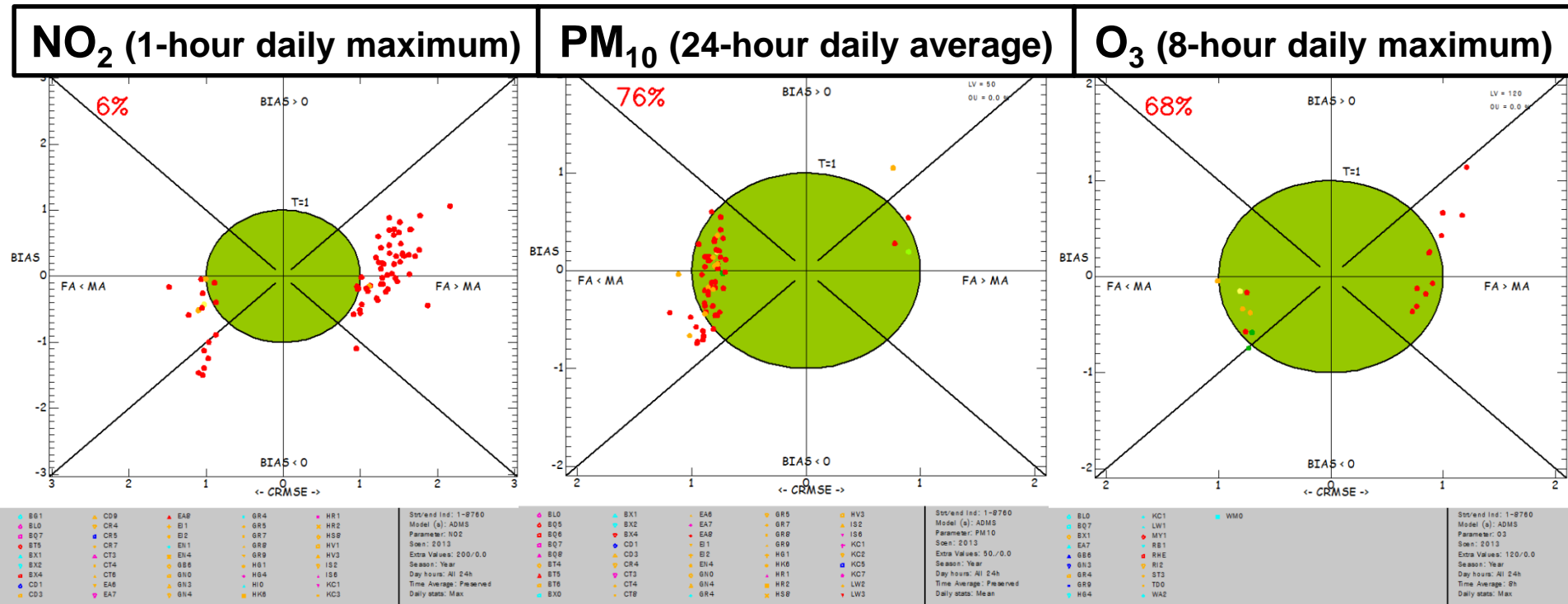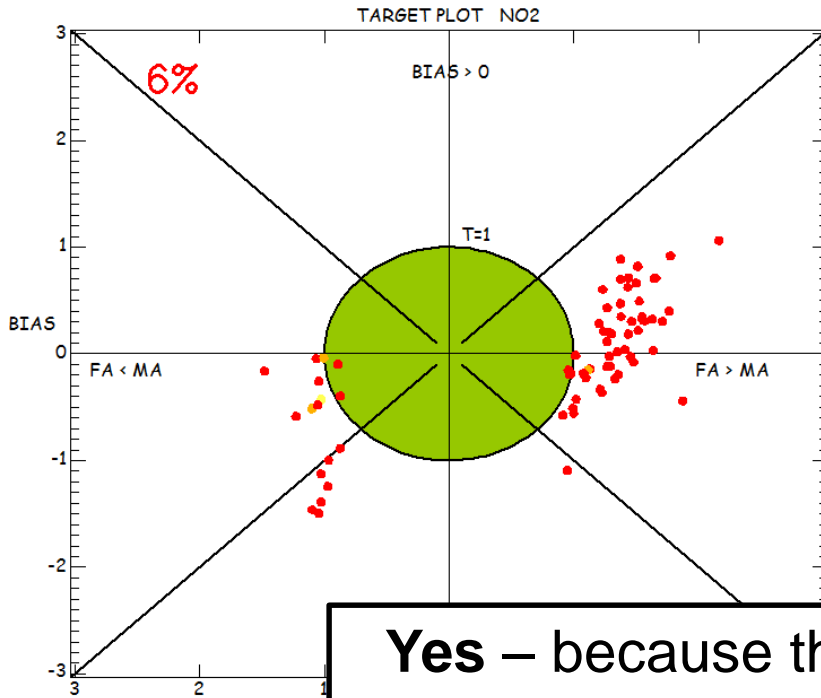| NO_2 (1-hour daily maximum) | PM_{10} (24-hour daily average) | O_3 (8-hour daily maximum) |

- Much better for version 5.1, but still not very well for the hourly objective: **NO_2 MAXIMUM DAILY VALUE**
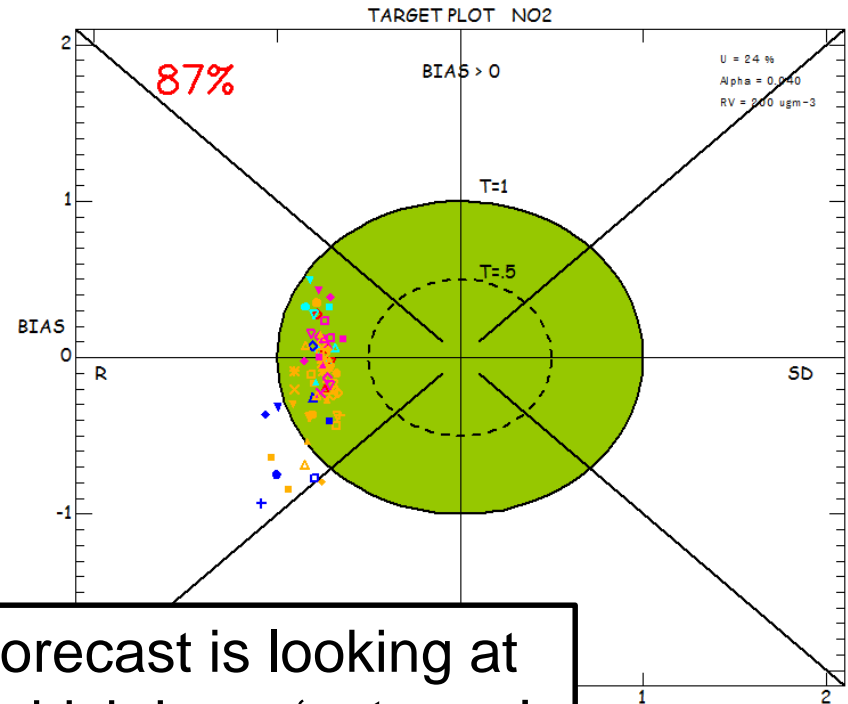
Model performance (DELTA version 5.1)

- Does this poor performance make sense when the model performs well in the standard Target plot (same dataset)?
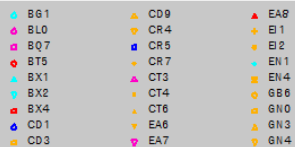

NO$_2$ – Forecasting target

NO$_2$ – Standard target

Yes – because the forecast is looking at the maximum daily, which is an 'extreme' statistic, compared to the hourly values analysed in the standard target

- Target for forecasting applications is related to the forecast being as good as a persistence model:

$$\text{Target} = \frac{\sqrt{\dfrac{1}{N}\sum_{i=1}^{N}(M_i - O_i)^2}}{\sqrt{\dfrac{1}{N}\sum_{i=1}^{N}(O_{i-1} - O_i)^2}}$$

where N is the number of observations, M_i is the modelled value and O_i is the observed value.

- This works when you have made a forecast for today (Day 1, say) and you are comparing to measured data from yesterday (Day 0).

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- Target for forecasting applications is related to the forecast being as good as a persistence model:

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- This works when you have made a forecast for today (Day 1, say) and you are comparing to measured data from yesterday (Day 0).

- Quite often, on Day 1, you also want to forecast for tomorrow, and the next day (Day 2 and Day 3). **You still only have the observation from Day 0.**

- The current Delta formulation:

$$Target_{forecast\_ji} = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(M_{ji} - O_i)^2}}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(O_{i-1} - O_i)^2}} \; with \_ j = i - n, ..., i$$

for Day 3 compares makes a comparison to the observations from Day 2. But on Day 1, you don't have the observations on Day 2 – only those from Day 0.

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- Suggestion: replace the proposed formulation with:

$$\text{Target}_{\text{forecast\_j}} = \frac{\sqrt{\dfrac{1}{N}\sum_{i=1}^{N}(M_i - O_i)^2}}{\sqrt{\dfrac{1}{N}\sum_{i=1}^{N}(O_{i-j} - O_i)^2}}$$

where N is the number of observations, M_i is the modelled value, j is the forecast day and O_i is the observed value.

- Take:

$$\text{Target} = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(M_i - O_i)^2}}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(O_{i-1} - O_i)^2}}$$

  where N is the number of observations, M_i is the modelled value and O_i is the observed value.

- If you had a period where the levels of pollution remained the same on a **day by day basis** (either constant, or varying diurnally), then
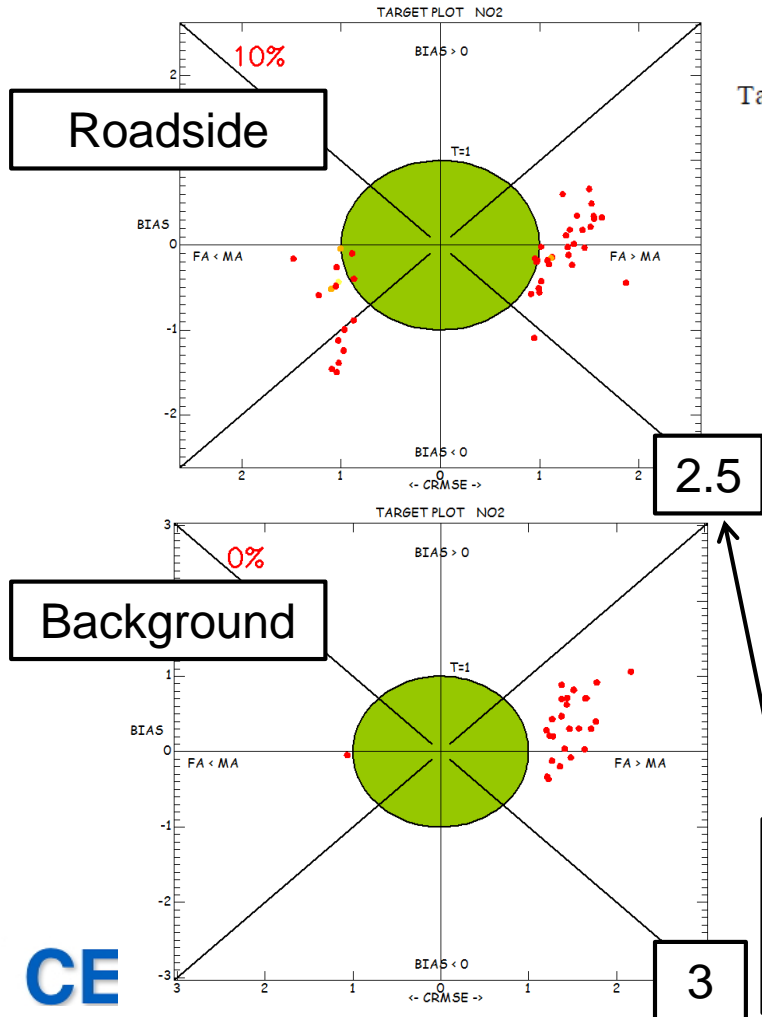
$$\frac{1}{N}\sum_{i=1}^{N}(O_{i-1} - O_i)^2 = 0$$
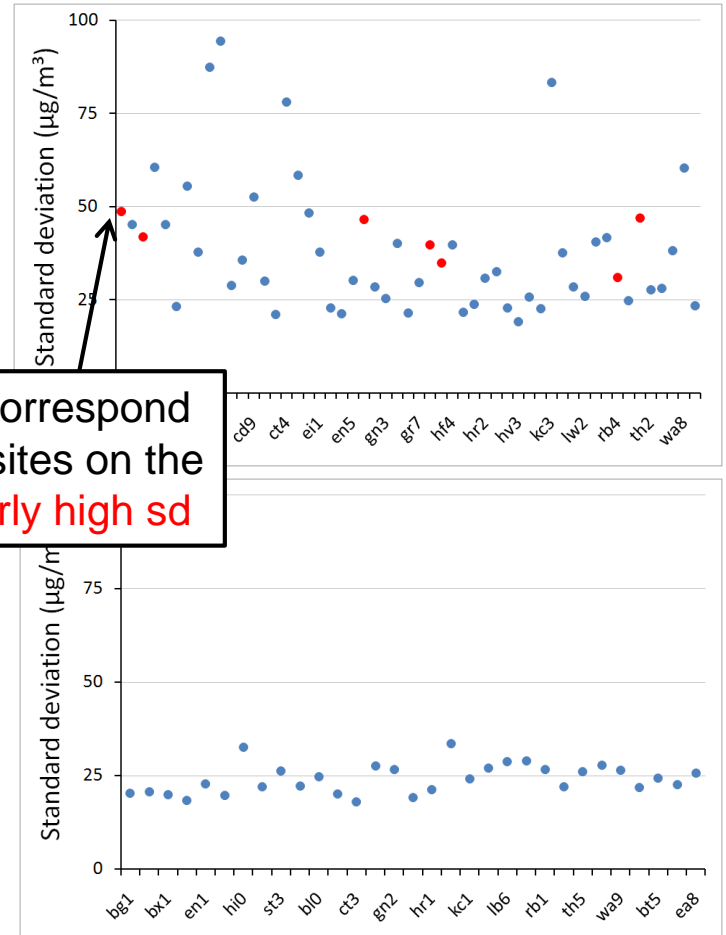
  so the target → infinity

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Is the forecasting target formulation robust?

- This means that at background sites, it is more difficult to get within the target than at roadside sites, because **the standard deviation (sd) of the observations (looking at daily maximum NO$_2$)** is lower.

$$\text{Target} = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(M_i - O_i)^2}}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(O_{i-1} - O_i)^2}}$$

Roadside

10%

2.5

Background

0%

Sites in red correspond to the 7 best sites on the Target i.e. fairly high sd

Note different scale

3

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Is the forecasting target formulation robust?

- This means that at background sites, it is more difficult to get within the target than at roadside sites, because **the standard deviation (sd) of the observations (looking at daily maximum NO$_2$)** is lower.

- Is it robust for the Target formulation to be independent on the sd of the observations?

$$\text{Target} = \frac{\sqrt{\dfrac{1}{N}\sum_{i=1}^{N}(M_i - O_i)^2}}{\sqrt{\dfrac{1}{N}\sum_{i=1}^{N}(O_{i-1} - O_i)^2}}$$

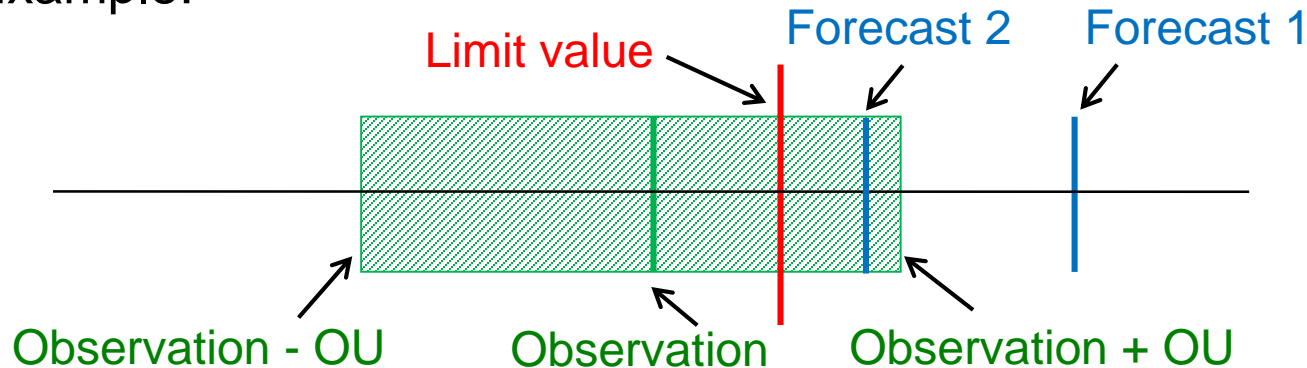- The formulation for the standard Target plot includes the sd:

$$MQO = \frac{RMSE}{2\,RMS_U} = \frac{1}{2}\frac{\sqrt{\sum(O_i - M_i)^2}}{\sqrt{\sum U_i^2}} \leq 1$$

$$RMS_U = k u_r^{RV}\sqrt{(1-\alpha)(\overline{O}^2 + \sigma_0^2) + \alpha * RV^2}$$

- Persistence is a better option at background sites than at kerbside sites – are we happy with this to be part of the formulation?

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- It is difficult to take into account uncertainty when considering alerts
- Example:

Observation < Limit value   BUT **Observation + OU > Limit value**
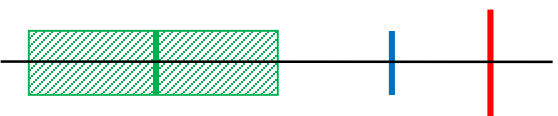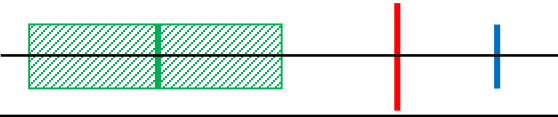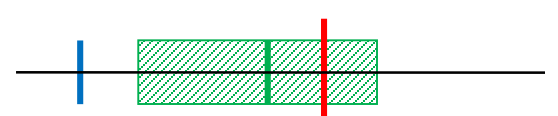
i.e. it is *possible* there should have been an alert

Proposed Delta method gives

- *Forecast 1 as a False Alert*
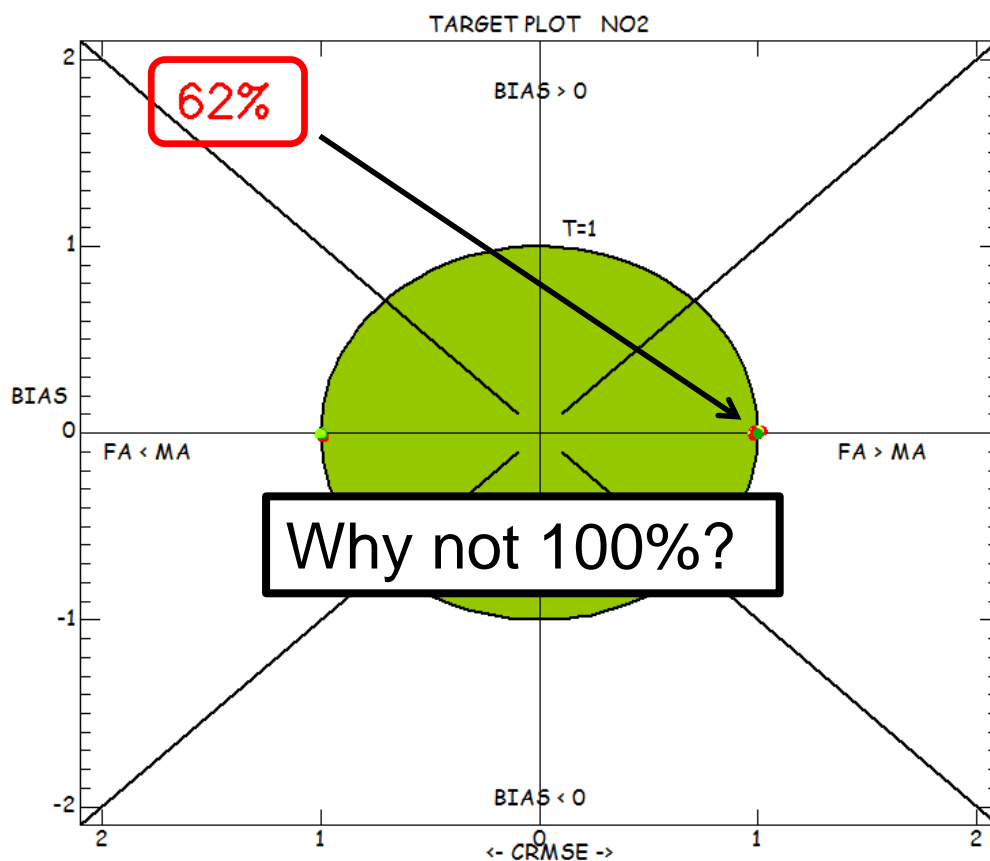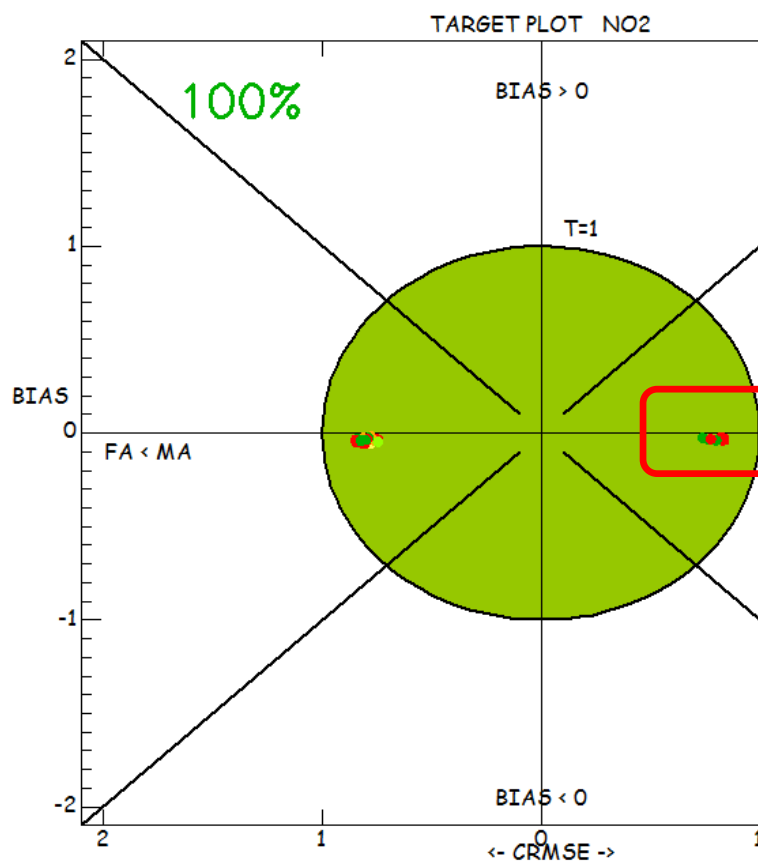- *Forecast 2 as a Correct Alert*

We would say this is incorrect because the methodology is taking into account biases, when it should be just looking at alerts

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Uncertainty – an alternative method?

Example case	Obs in relation to LV?	Obs alert?	Mod in relation to LV?	Mod alert?	Status
	$O_+ <$ LV	No	M < LV	No	GA-
	$O_+ <$ LV	No	M > LV	Yes	FA
	$O_- <$ LV & $O_+ >$ LV	A: Yes (conservative) B: No (cautious) C: Same as model	M < LV	No	MA GA- GA-
	$O_- <$ LV & $O_+ >$ LV	A: Yes (conservative) B: No (cautious) C: Same as model	M > LV	Yes	GA+ FA GA+
	$O_- >$ LV	Yes	M < LV	No	MA
	$O_- >$ LV	Yes	M > LV	Yes	GA+

Key: Observed value range | Limit value | Model value

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Specific issues:
Accuracy of the persistence plots

- Persistence plot for NO_2

Specific issues:
Accuracy of the persistence plots

- Persistence plots for PM$_{10}$ & O$_3$

Different alarm thresholds

- Forecast target diagram colouring and x-axis variation relate to a specific alert threshold:

LV = 50 i.e. the daily limit value for a moderate PM$_{10}$ episode

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Different alarm thresholds

- Forecast target diagram colouring and x-axis variation relate to a specific alert threshold

- Usually there are a series of thresholds, eg Daily Air Quality Index (DAQI):

Boundaries Between Index Points for Each Pollutant

Use the tabs below to view the bandings for each pollutant.

| Ozone | Nitrogen Dioxide | Sulphur Dioxide | PM2.5 Particles | **PM10 Particles** |

PM$_{10}$ Particles

Based on the daily mean concentration for historical data, latest 24 hour running mean for the current day.

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
µg/m³	0-16	17-33	34-50	51-58	59-66	67-75	76-83	84-91	92-100	101 or more

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Specific issues:
Different alarm thresholds

- Forecast target diagram colouring and x-axis variation relate to a specific alert threshold

- Usually there are a series of thresholds, eg Daily Air Quality Index (DAQI)

- Is there a way for the tool to calculate the target relating to all thresholds at the same time, rather than having to re-run for each pollutant and each threshold?

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Suggestions & minor issues

- Regarding suggestions for the Summary Performance Report:
  - For Alert thresholds, show
    - Probabilty of Detection
    - False Alarm Ratio
  - To assess performance against indices
    - Show % correct indices
    - Show % index values within ±1 observed

- 'GA', 'GA+' & 'GA-' are not defined in the document

- The Forecast Target plot has a key that is now redundant

- Is there a way to output the actual statistics eg details of number of modelled & observed alerts, missed alerts, false alerts?

- The 'click and display site information' feature doesn't seem to be working on the Forecast Target plot

- Some of the Target plots have information in the top right hand corner, and some don't.

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Summary

- London forecasting system performance is better with using Delta 5.1 compared to 3.6

- The Target formulation for forecasting may need further development, specifically with respect to:
    - Forecasts for more than one day ahead
    - Assessment of different types of station
    - Allowing for uncertainty in the alert thresholds
    - Accuracy of the persistence plots

- Various other suggestions and minor issues include:
    - POD, FAR and index performance in the Summary statistics
    - Improvements to the documentation
    - Click and display information not working on Target plot
    - Redundant key on Target plot
    - Inconsistency of key on Target plot
    - Output Alert statistics

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