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Barcelona Supercomputing Center
Centro Nacional de Supercomputación

# CALIOPE forecasts evaluated by DELTA

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**WG1 Assessment – CCA: Forecast**
**FAIRMODE Technical Meeting . April 28-29, 2014. Kjeller (Norway)**

# CALIOPE Air Quality Forecast System

## CALIOPE modules

**Meteorology**
- WRF-ARWv3.5
- 38 sigma levels (top 50 hPa)
- IBC: GFS (NCEP)
- 33 layers/50 hPa

**Emission**
- HERMESv2
- EU: HERMES-DIS (EMEP data)
- Spain: HERMES-BOUP

**Chemistry**
- CMAQv5.0.1
- CB05/AERO5
- BC: NCAR MOZART4
- 15 layers/ 50 hPa

**Desert dust**
- BSC-DREAM8bv2
- Desert PM10 and PM2.5

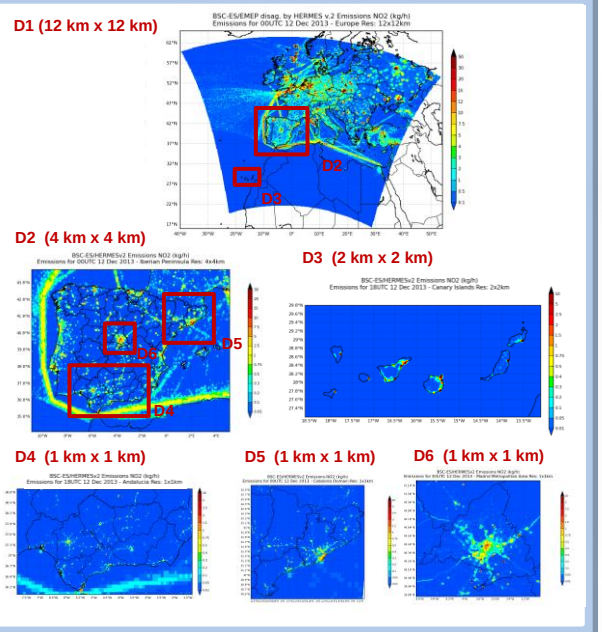
**Post-process**
- Kalman filter (point and 2D)

**Air Quality Forecast**

$O_3$, $NO_2$, $SO_2$, CO, PM10, PM2.5, Benceno

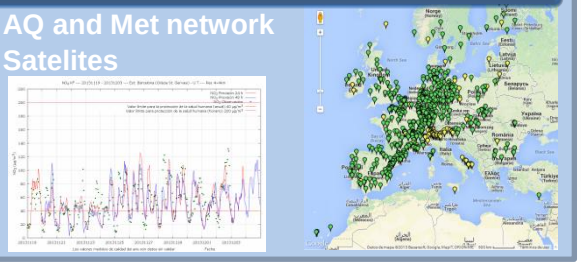
## Forecast 48h

- Maps: concentratión, emission, meteo.
- Air Quality Index



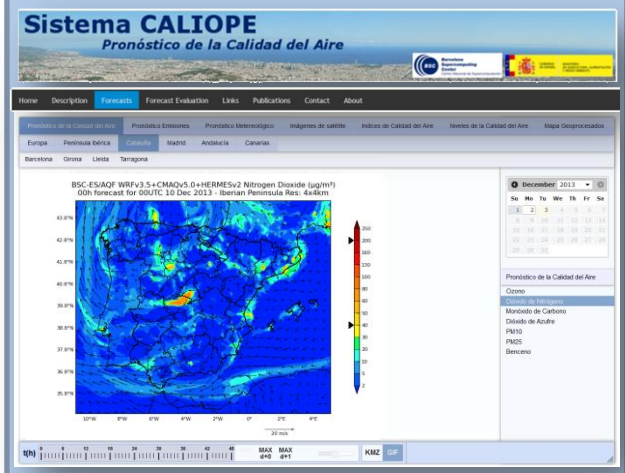

## NRT evaluation

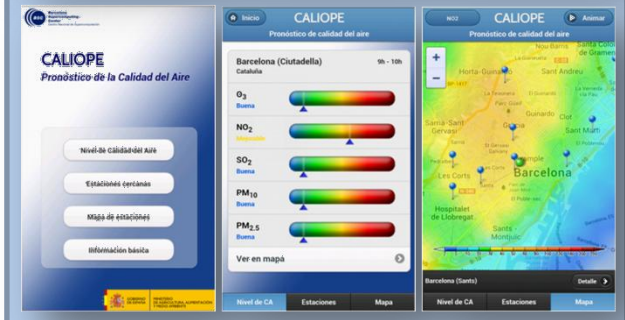
- AQ and Met network
- Satelites



## Difusion

- Web (www.bsc.es/caliope )
- Smartphone



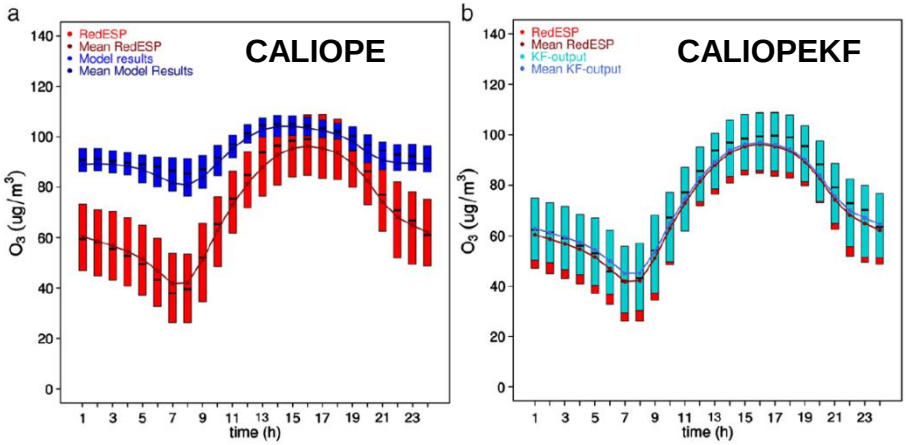




ANDROID APP ON Google play

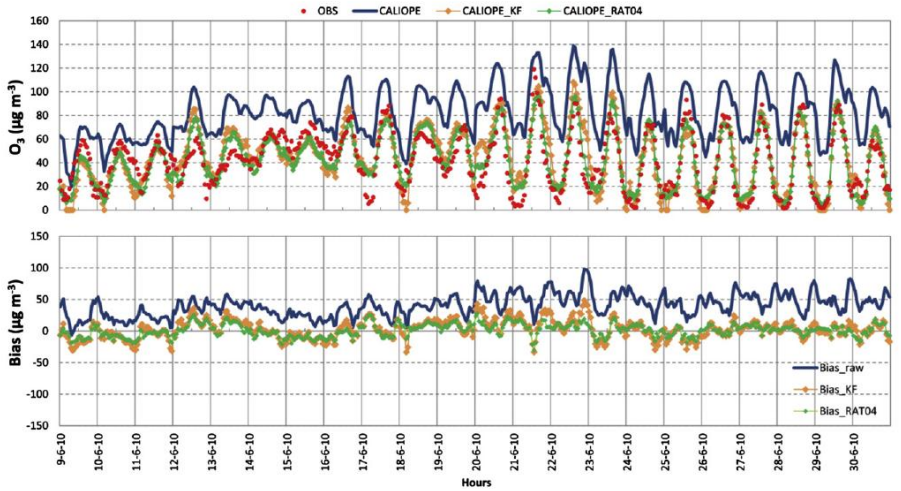
Available on the App Store

# Experience with bias-correction techniques in CALIOPE

- KF improves $O_3$ forecast (timing, daily variability) bias and capability to predict exceedances of air quality thresholds.
- Among different bias-correction techniques, KF was more robust in terms of the absence of observation and computational cost.
- KF is applied for $O_3$, $NO_2$, and $PM_{10}$




Sicardi et al. (2011): STOTEN- Assessment of Kalman filter bias-adjustment technique to improve the simulation of ground-level ozone over Spain




Borrego et al. (2011): AE- How bias-correction can improve air quality forecasts over Portugal

# Objective

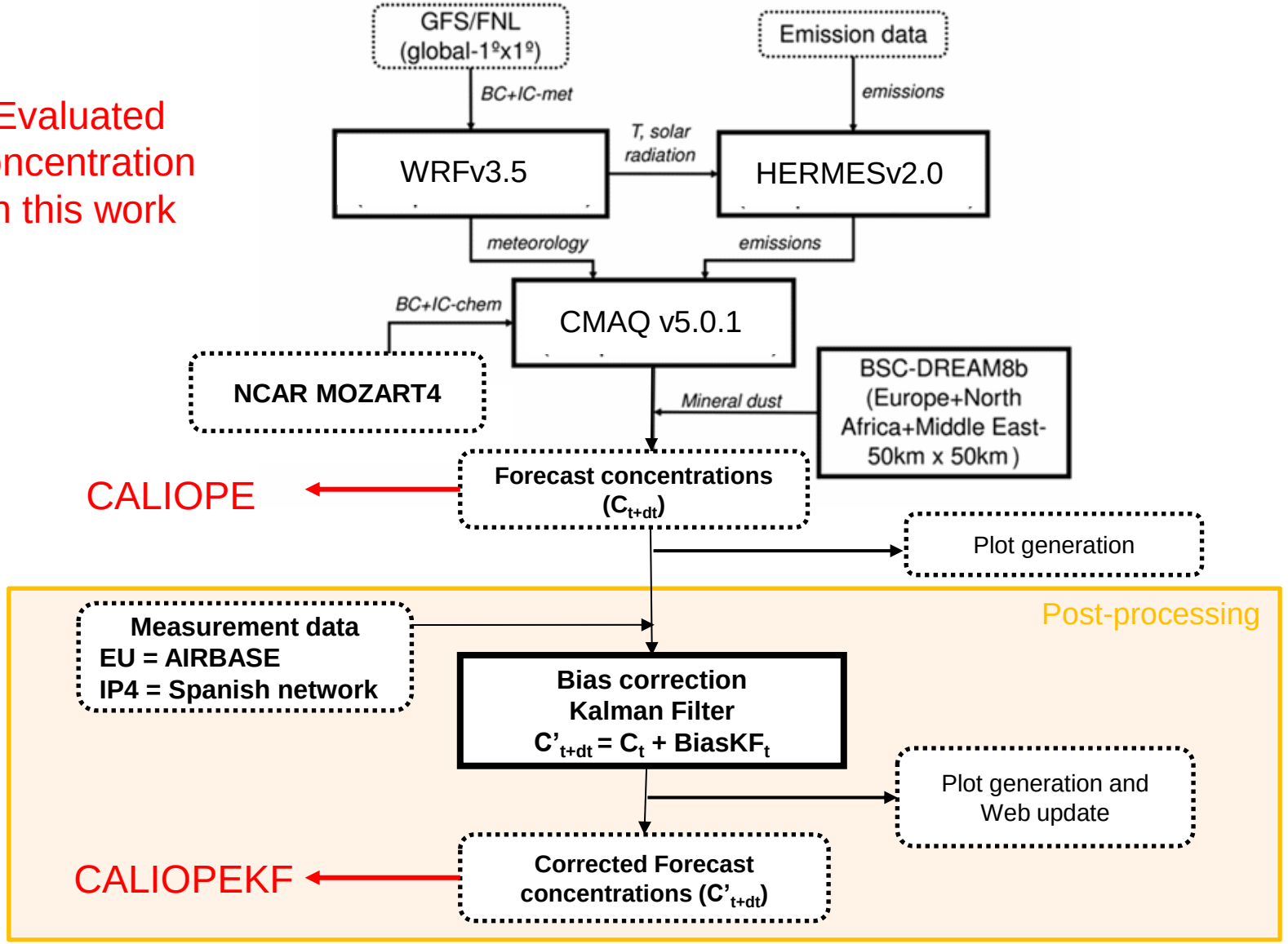
- Using the DELTA tool (benchmarking and exploration) to evaluate the CALIOPE performance, with a special focus on:
  - Analysing the effect of bias correction techniques in terms of the MQO.
  - Testing the Target Indicator for forecasting applications.

Case study

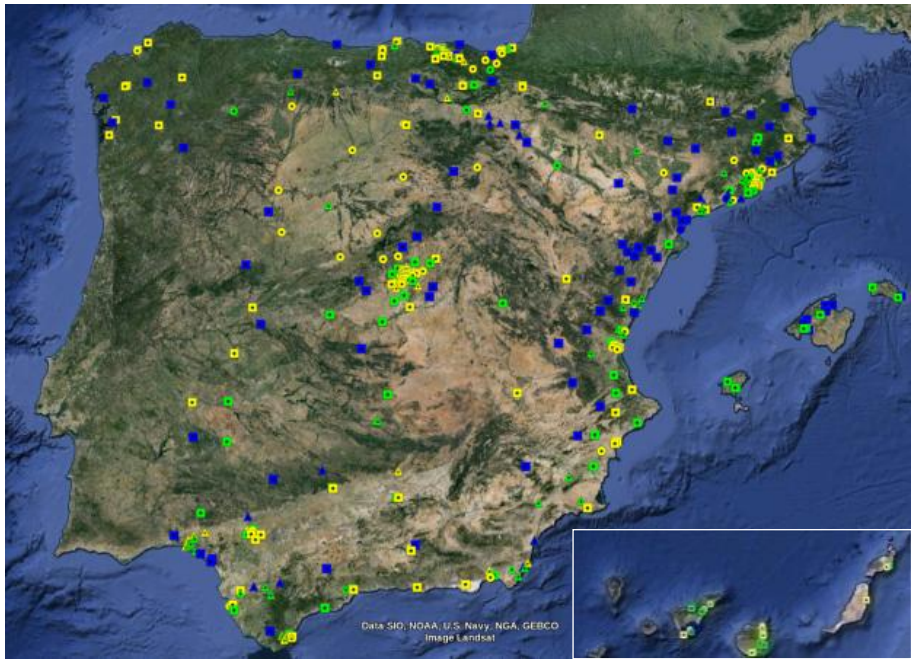
- **Modelling system**: CALIOPE-AQFS (4 km x 4 km)
- **Domain**: Spain
- **Annual evaluation**: 2013
- **Evaluated pollutants**: $O_3$ and $NO_2$
- **Observation**: Spanish air quality monitoring network.
- **DELTA tool v3.6**:
  init.ini: ELAB_FILTER_TYPE=ADVANCED

# Forecast post-processing within CALIOPE-AQFS

Evaluated concentration in this work

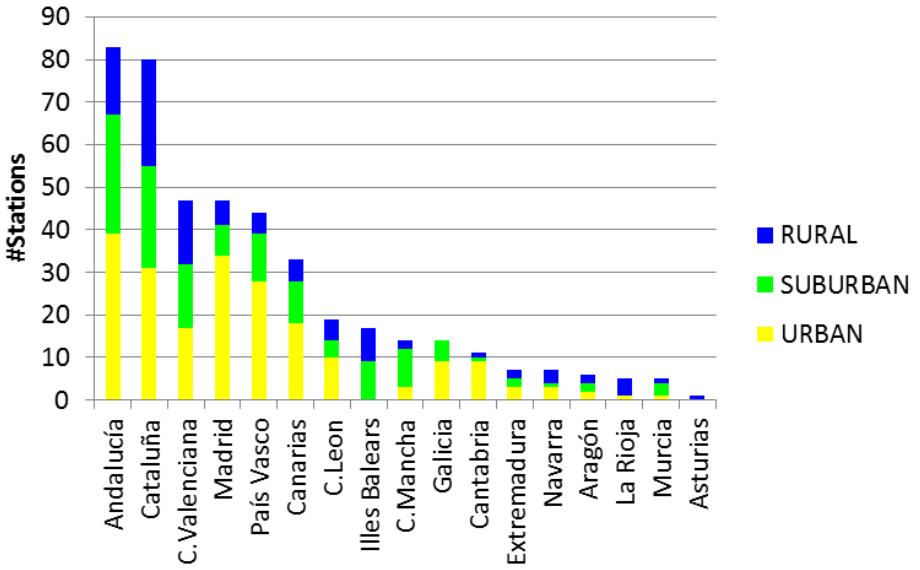


# AQ Monitoring Network in 2013: Near Real Time (NRT) observations




| | # stations | %U | %S | %R |
|---|---|---|---|---|
| $O_3$ | 290 | 42 | 30 | 29 |
| $NO_2$ | 345 | 48 | 29 | 23 |
| $SO_2$ | 250 | 48 | 29 | 20 |
| PM10 | 223 | 51 | 29 | 20 |
| PM2.5 | 43 | 42 | 33 | 26 |

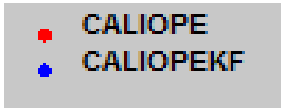
445 stations = 117 Rural – 127 Suburban – 201 urban



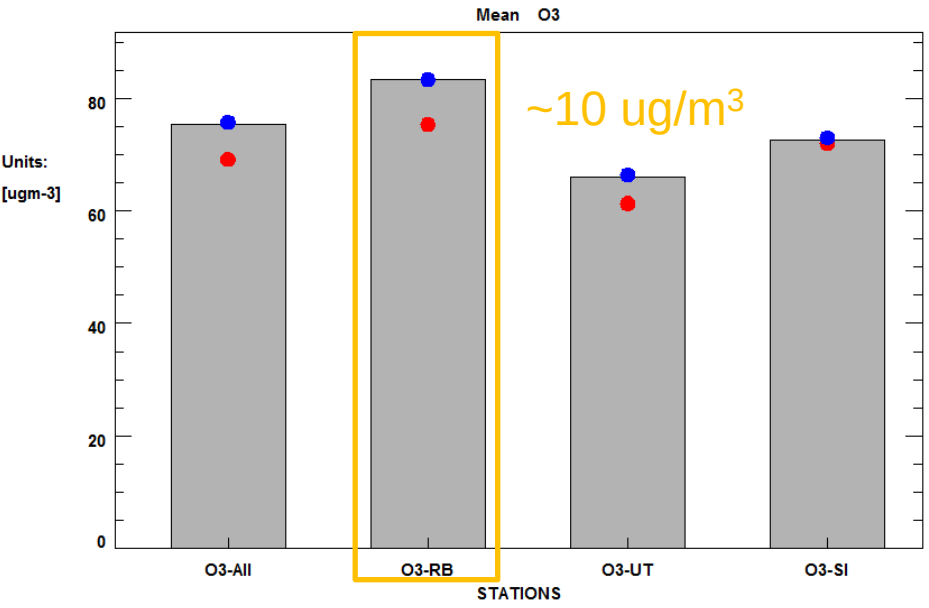

**Institutions providing data in NRT during 2013:**

1. La Agencia Europea de Medioambiente (EEA)
2. Generalitat de Catalunya
3. Gobierno de Cantabria
4. Junta de Andalucia
5. Gobierno de Canarias
6. Comunidad de Madrid
7. Ayuntamiento de Madrid
8. Govern de les Illes Balears
9. Xunta de Galicia
10. Gobierno de La Rioja
11. Gobierno Extremadura
12. Junta de Castilla y León
13. Junta de Castilla-La Mancha
14. Govern d'Andorra

# Bar plot in DELTA tool



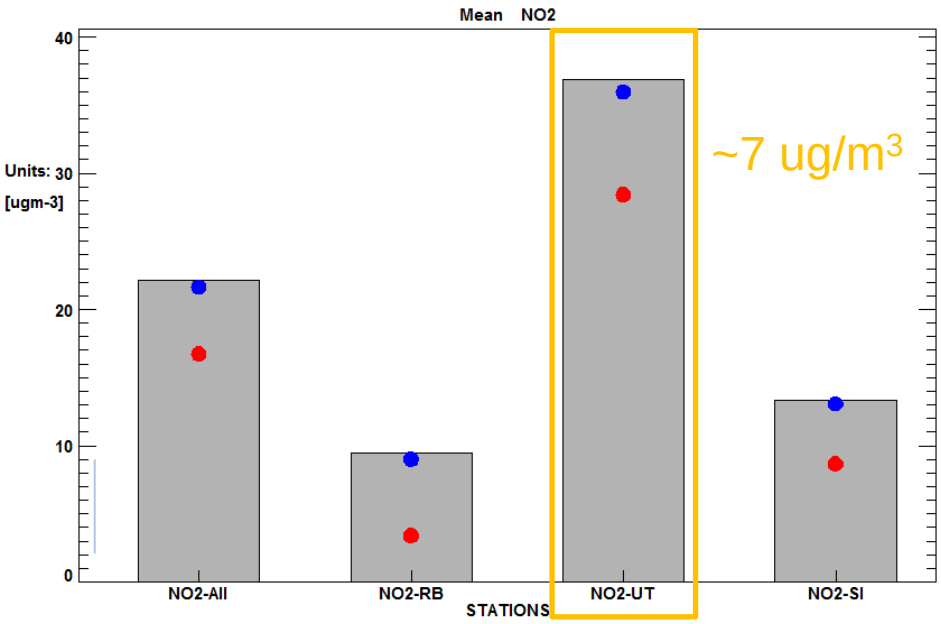

## $O_3$




$O_3$ period
(April to September)

Strt/end Ind: 2161-5832
Station: -1
Parameter: O3
Scen: 2013
Extra Values: No
Season: Year
Day hours: All 24h
Time Average: Preserved
Daily stats: preserved

## $NO_2$

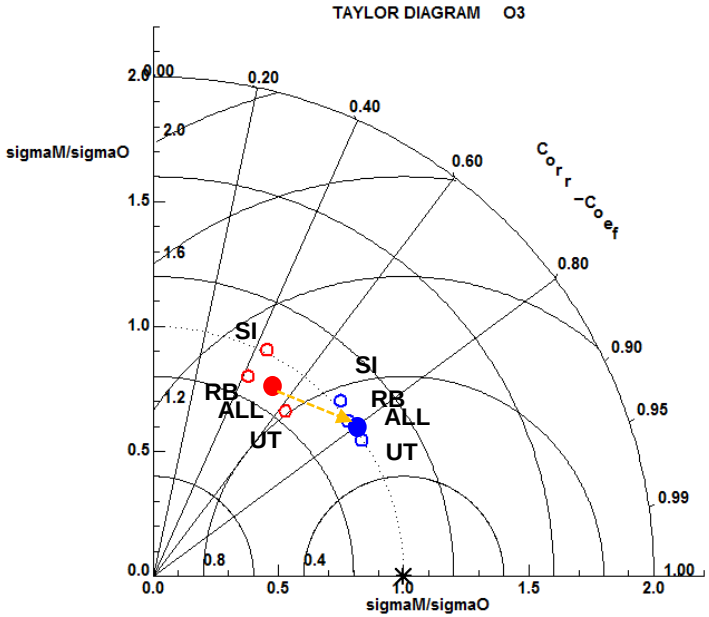



Strt/end Ind: 1-8760
Station: -1
Parameter: NO2
Scen: 2013
Extra Values: No
Season: Year
Day hours: All 24h
Time Average: Preserved
Daily stats: preserved

# Taylor diagram in DELTA tool

CALIOPE
CALIOPEKF

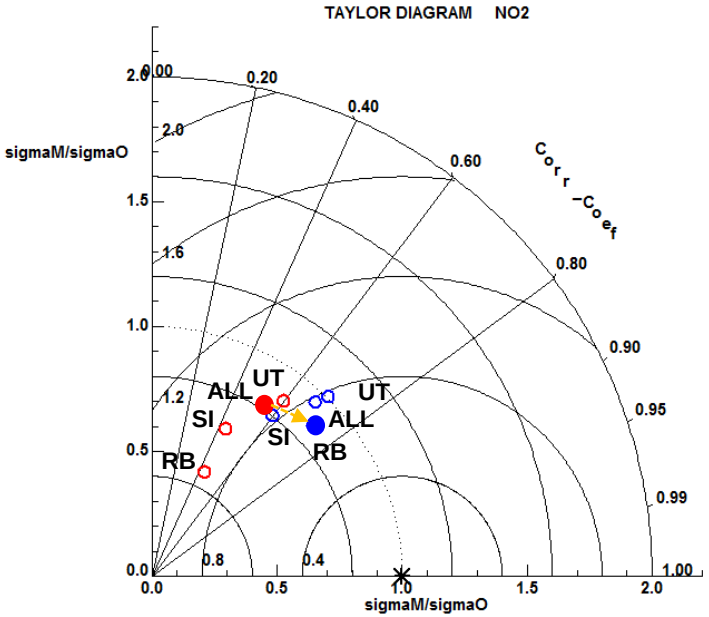
## $O_3$




CALIOPE
CALIOPEKF

Strt/end Ind: 1-8760
Station: -1
Parameter: O3
Scen: 2013
Extra Values: No
Season: Year
Day hours: All 24h
Time Average: Preserved
Daily stats: Mean

## $NO_2$



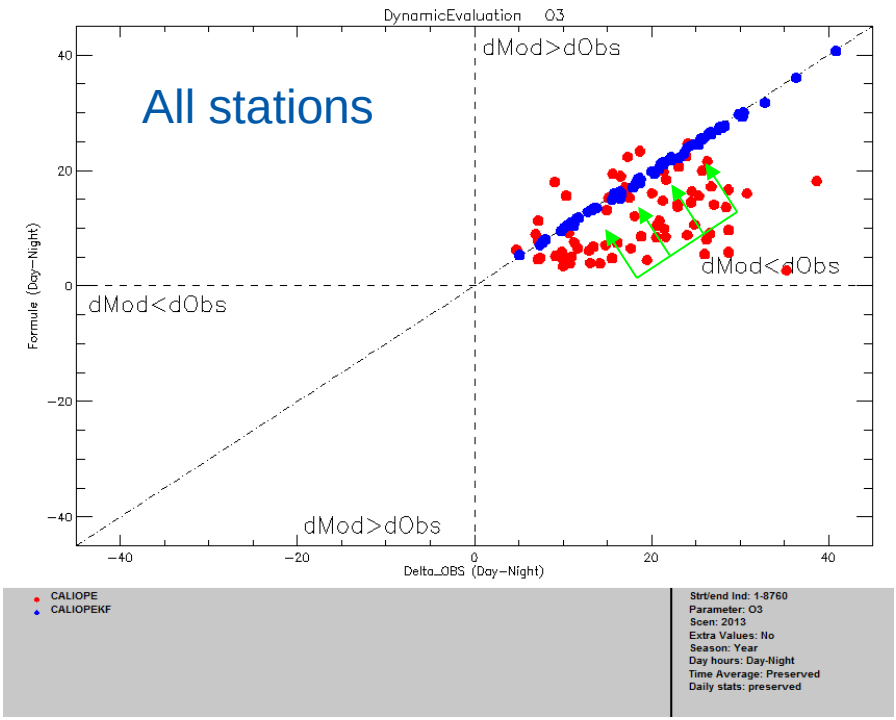

CALIOPE
CALIOPEKF

Strt/end Ind: 1-8760
Station: -1
Parameter: NO2
Scen: 2013
Extra Values: No
Season: Year
Day hours: All 24h
Time Average: Preserved
Daily stats: Mean

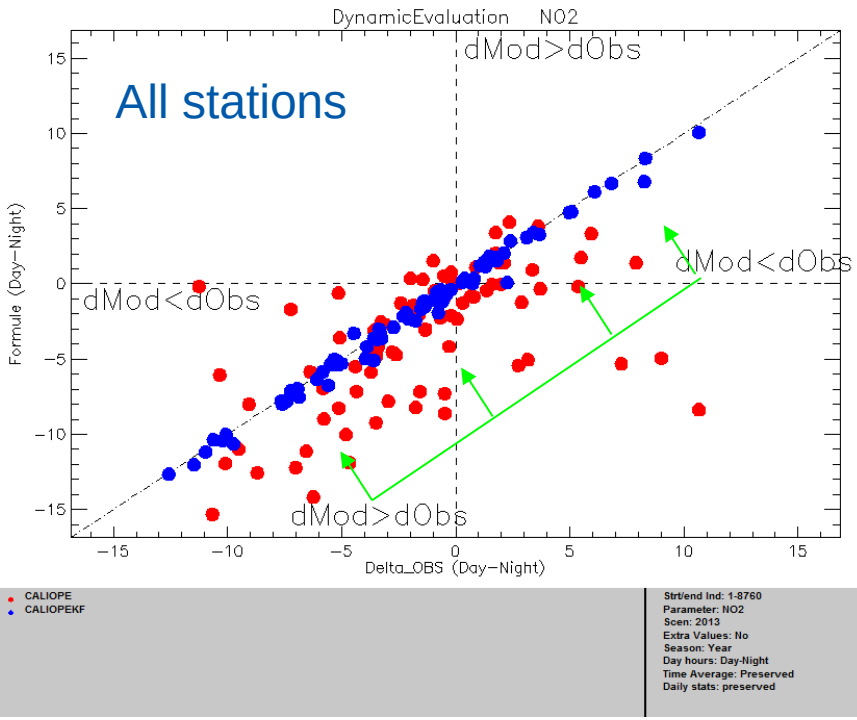
# Dynamic evaluation: day/night

CALIOPE
CALIOPEKF

## $O_3$

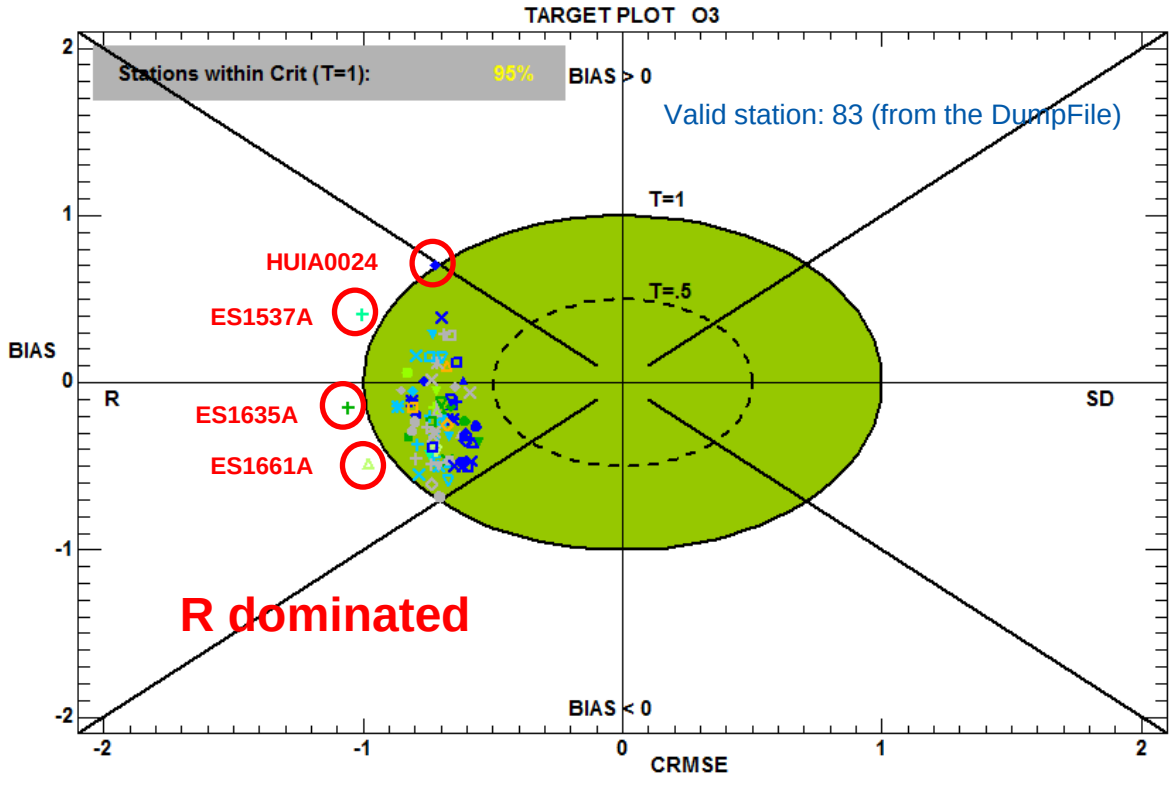



## $NO_2$




Day-night variability (almost negative) is significantly improved with KF

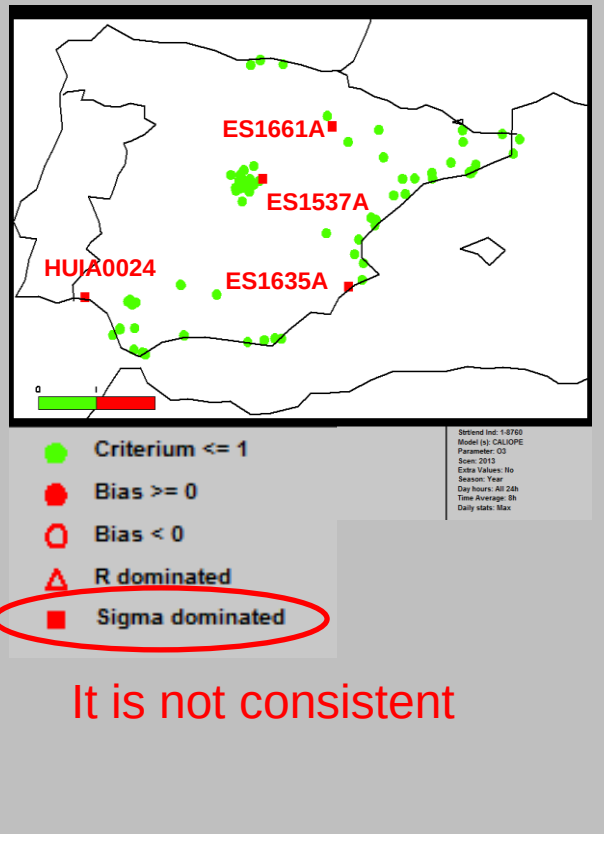
# Target Plot and GeoMap



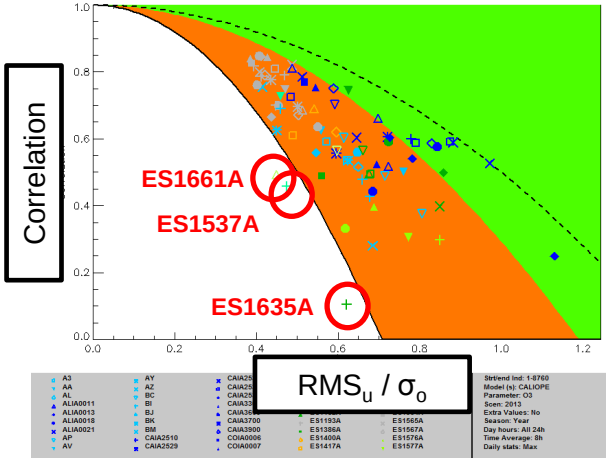

**From Target plot description in User**

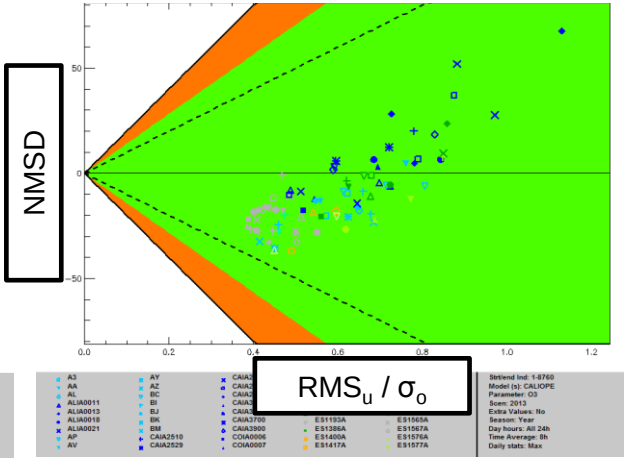
$$\frac{NMSD}{\sqrt{2(1-R)}} \begin{cases} > 1 \rightarrow \text{SD dominates on R (left)} \\ < 1 \rightarrow \text{R dominates on SD (right)} \end{cases}$$

## GeoMap (Target)



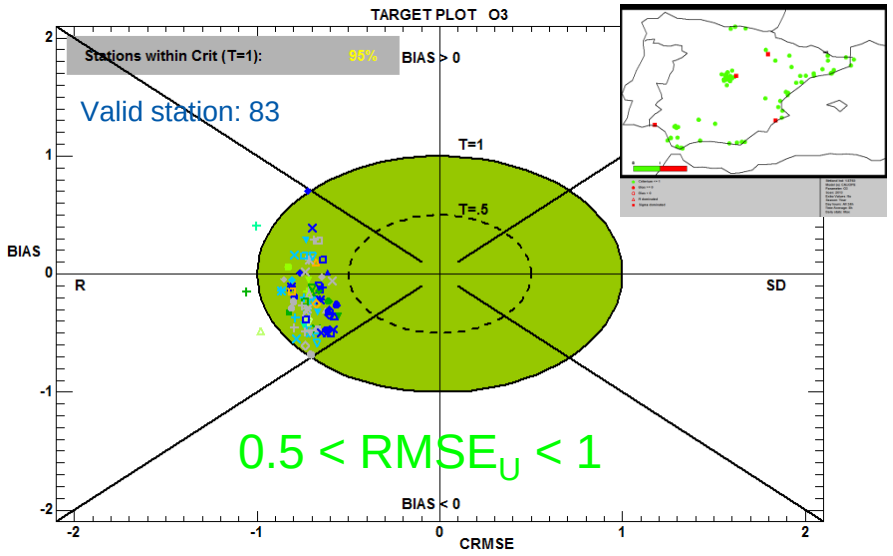

It is not consistent



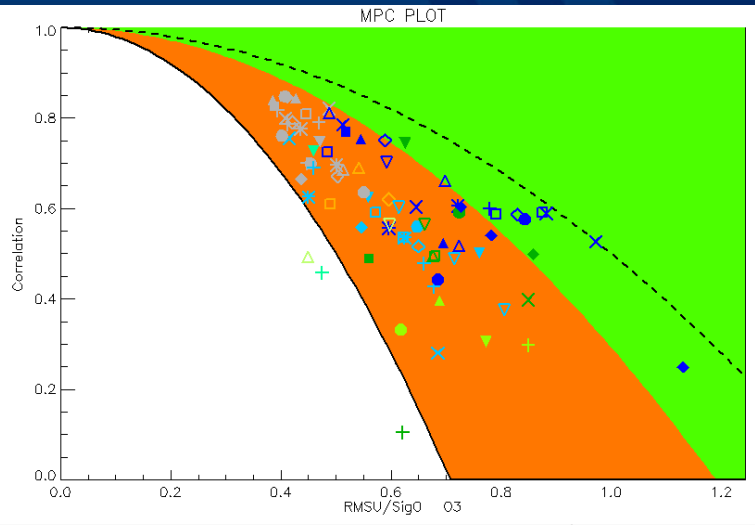



# Target Indicator: 8h Max daily $O_3$

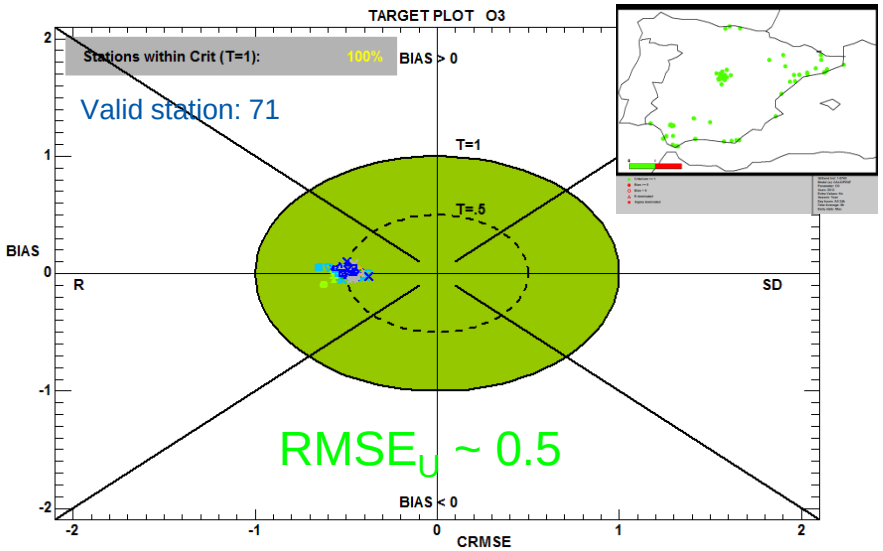
CALIOPE



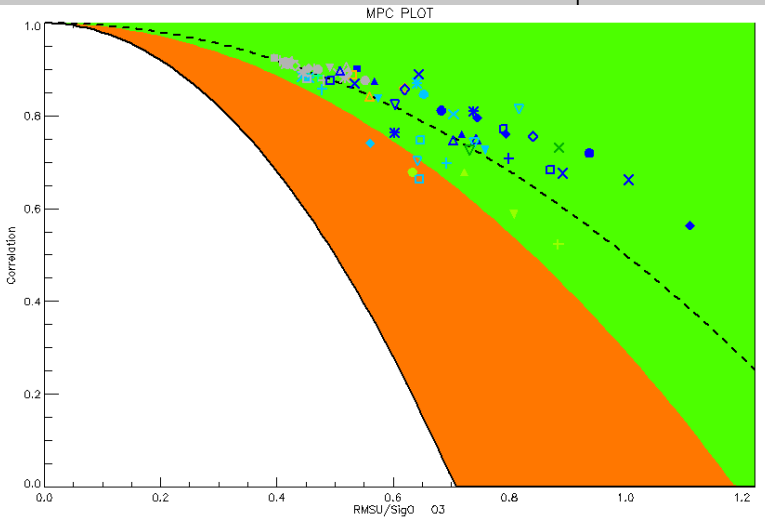

$0.5 < RMSE_U < 1$




CALIOPEKF

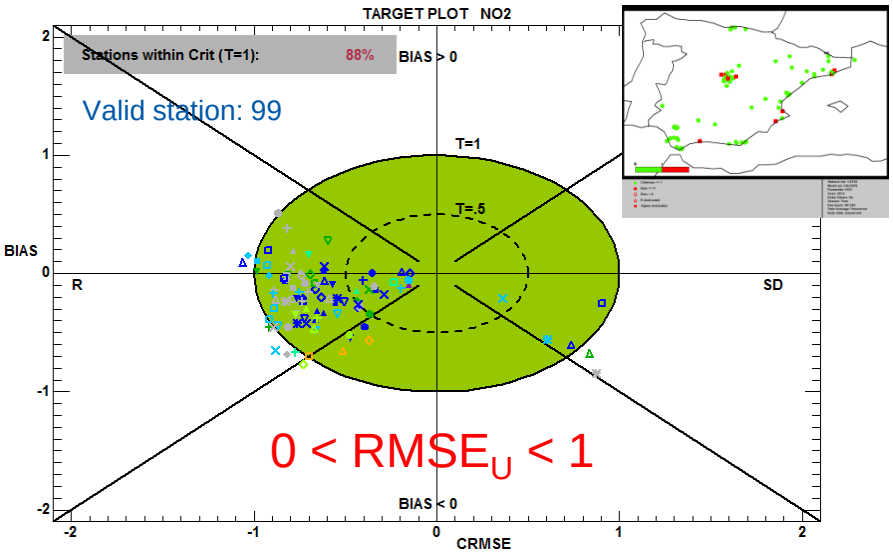


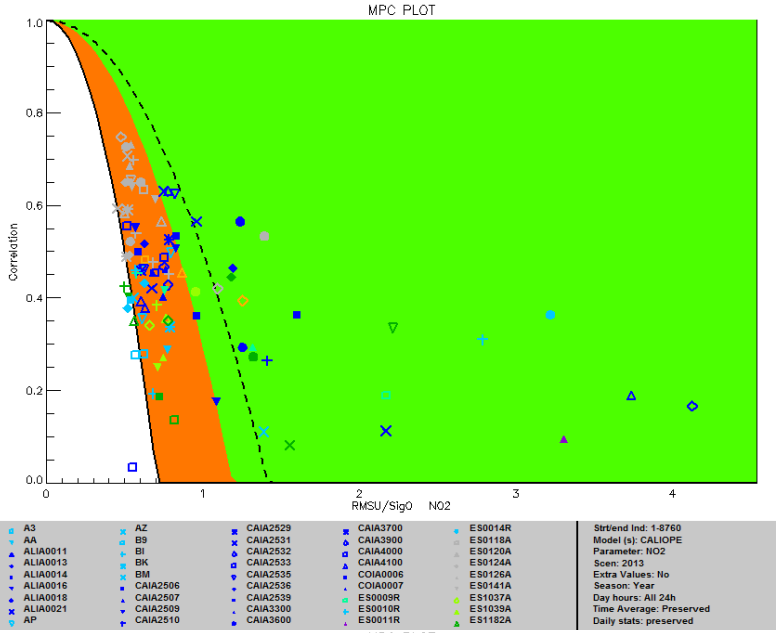

$RMSE_U \sim 0.5$



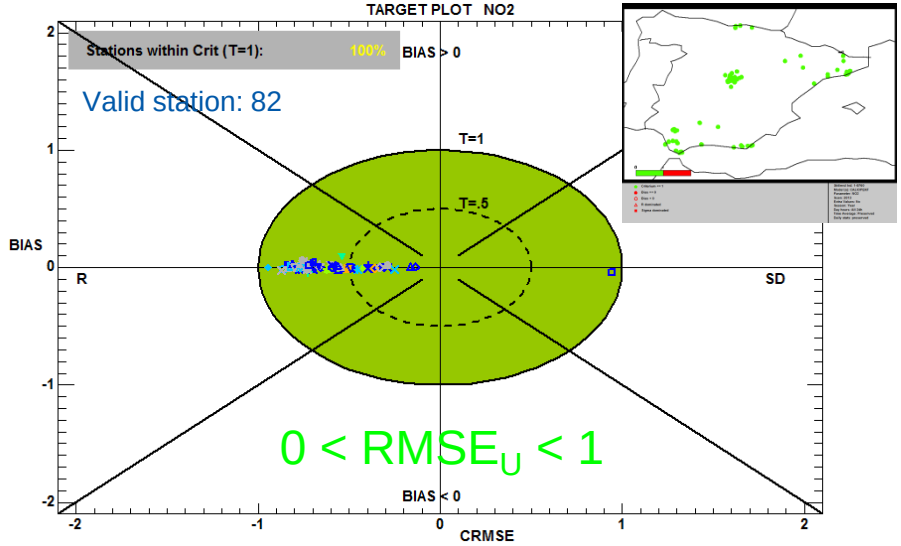
# Target Indicator: hourly $NO_2$

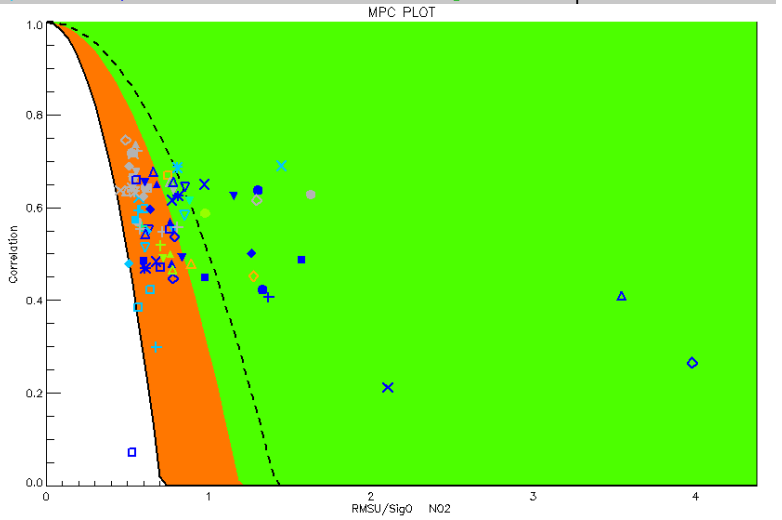
CALIOPE




CALIOPEKF



# Suggested MQO for forecast

Previously …

$$RMSE_U = \frac{\sqrt{\frac{1}{N}\sum (O_i - M_i)^2}}{2U}$$

Evaluate if models are good enough based on observation uncertainty

New target indicator for forecast application (Thunis et al., 2012, FAIRMODE SG4 Report):

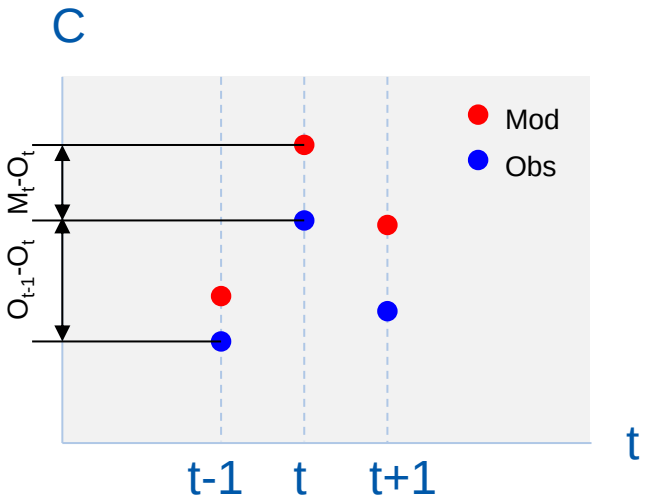
$$\text{Target} = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(M_i - O_i)^2}}{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(O_{i-1} - O_i)^2}}$$

Where N is the length of the time series.

“normalize by a quantity representative of the day-to-day variations”

- Comparison between $|M_t - O_t|$ vs $|O_{t-1} - O_t|$

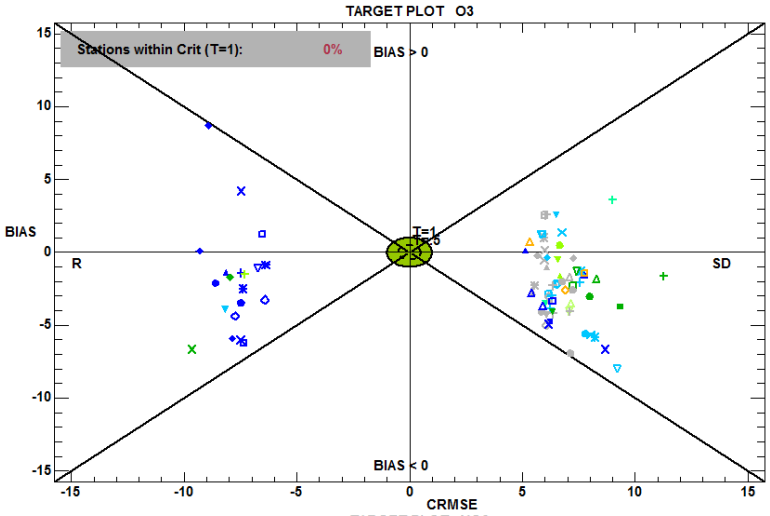
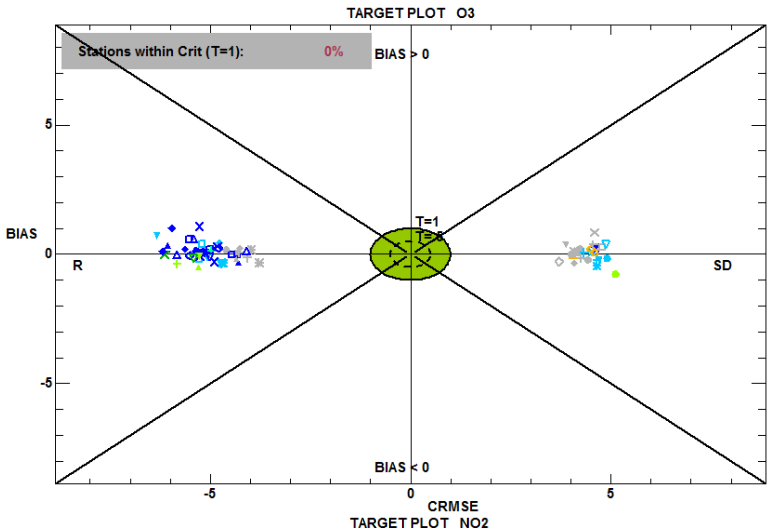
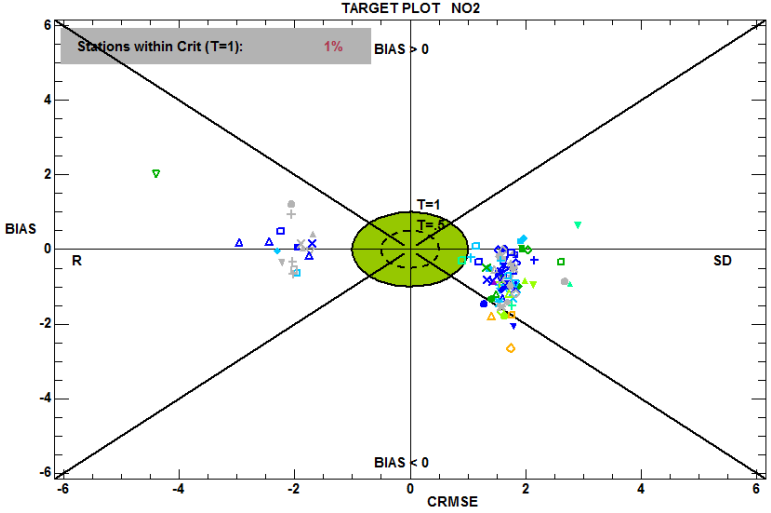
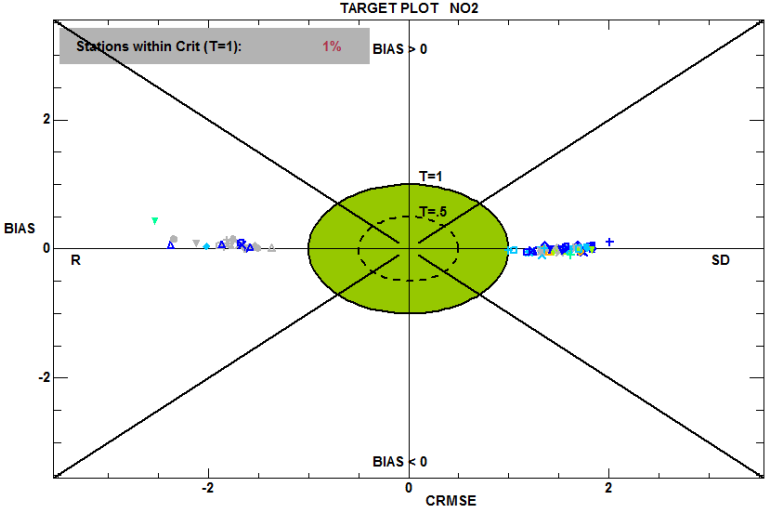
Any sense?




- $O_{t-1} - Ot$ depends on:
  - Δt = hourly, daily, annual, etc.
  - Pollutant: e.g. $O_3$ marked daily cycle
  - Station type: e.g. $NO_2$ daily cycle at UT vs remote rural background station
  - Observation uncertainty of the pollutant: in forecast we work with no validated data!!

# MQO for forecast in CALIOPE

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

| | CALIOPE | CALIOPEKF |
|---|---|---|
| $O_3$ MAX 8h |  |  |
| $NO_2$ HOURLY |  |  |





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# Conclusions and discussion (1/2)

- Evaluation of the effect of bias correction technique with Delta tool v 3.5. After applying KF (CALIOPE vs CALIOPEKF):
  - Reduction of annual mean bias for $O_3$ (RB, ~10 ug/m$^3$) and $NO_2$ (UT, ~7 ug/m$^3$)
  - Increasing of annual r from 0.5-0.6 to 0.8 in $O_3$ and 0.5-0.6 to 0.7-0.8 for $NO_2$.
  - Higher agreement obs/mod for the day/nigth variability.
  - **CALIOPE** fulfils the criterion for $RMSE_U$ (< 1) for **8hMax $O_3$** (95%) but not for **Hourly $NO_2$** (only 88%)
  - **CALIOPEKF** fulfils the criterion (100%) for **8hMax $O_3$** and **Hourly $NO_2$** to be acceptable for regulatory applications.
- New target for forecast applications:
  - The normalization with the observation variability, does it significant sense?
  - A new target for forecast (with regulatory orientation) should answer:
    - Is the model good enough to forecast exceedances of EU limit values?:
      - Categorical statistics (CSI, POD, FAR) suggested by Kang et al. (2005)
      - Categorical statistics normalized by area (aH, aFAR, WSI) suggested by Kang et al. (2007).
    - How the model performance degenerate with the forecast period (24h, 48h, 72h)? What is the confidence of that?

# Conclusions and discussion (2/2)

## About the DELTA tool v3.6

- DELTA tool is useful for exploratory analysis:
  - It harmonizes the evaluation techniques (e.g. statistic calculation) and it includes MQO acceptance.
  - Representative statistical diagrams and indicators: e.g. Dynamic evaluation, spatial evaluation, GeoMap.

- Suggestions:
  - Problem with the preprocessor MODEL.csv to netcdf. csv_to_modeltypeV2.sav is working but with warnings.
  - Indicate the number of stations (valid, selected, rejected) in each plot (e.g. in target plot).
  - Valued outputs:
    - ~/DELTATOOL/dump/DumpFile.txt → Target plot
    - ~/DELTATOOL/dump/MODELNAME.txt → Summary Statistics

- Linux version? Scripting capabilities?

# Thank you for your attention

Contact: maria.pay@bsc.es