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UMOS-AQ

Updatable Model Output Statistics – Air Quality

Introduction, Description, Latest changes and Future developments

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Overview

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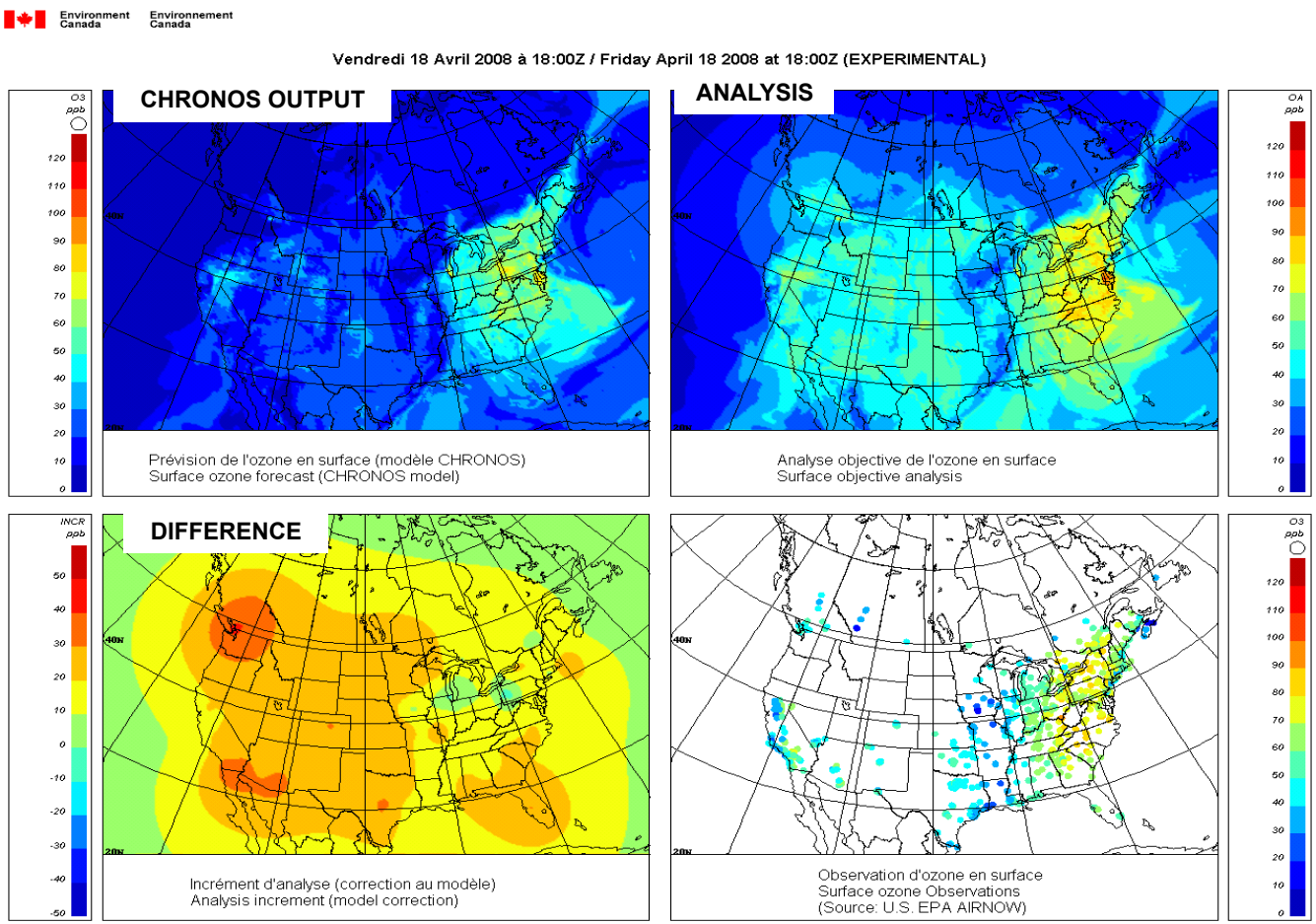
Motivation: Models have errors



Why statistical post-processing?

- Can compensate for models' inherent systematic errors
- Take into account scales and phenomena not yet resolved by dynamical models
- Possibility of probabilistic forecast
- Generate forecasts (predictands) that may not exist directly in the model's output (e.g. 8hrs avg. [O3], AQHI index, etc.)
- Possibility of combining sources of information (e.g. chemistry model, meteorological model, back trajectories, etc.)
- etc.

Why UMOS ?

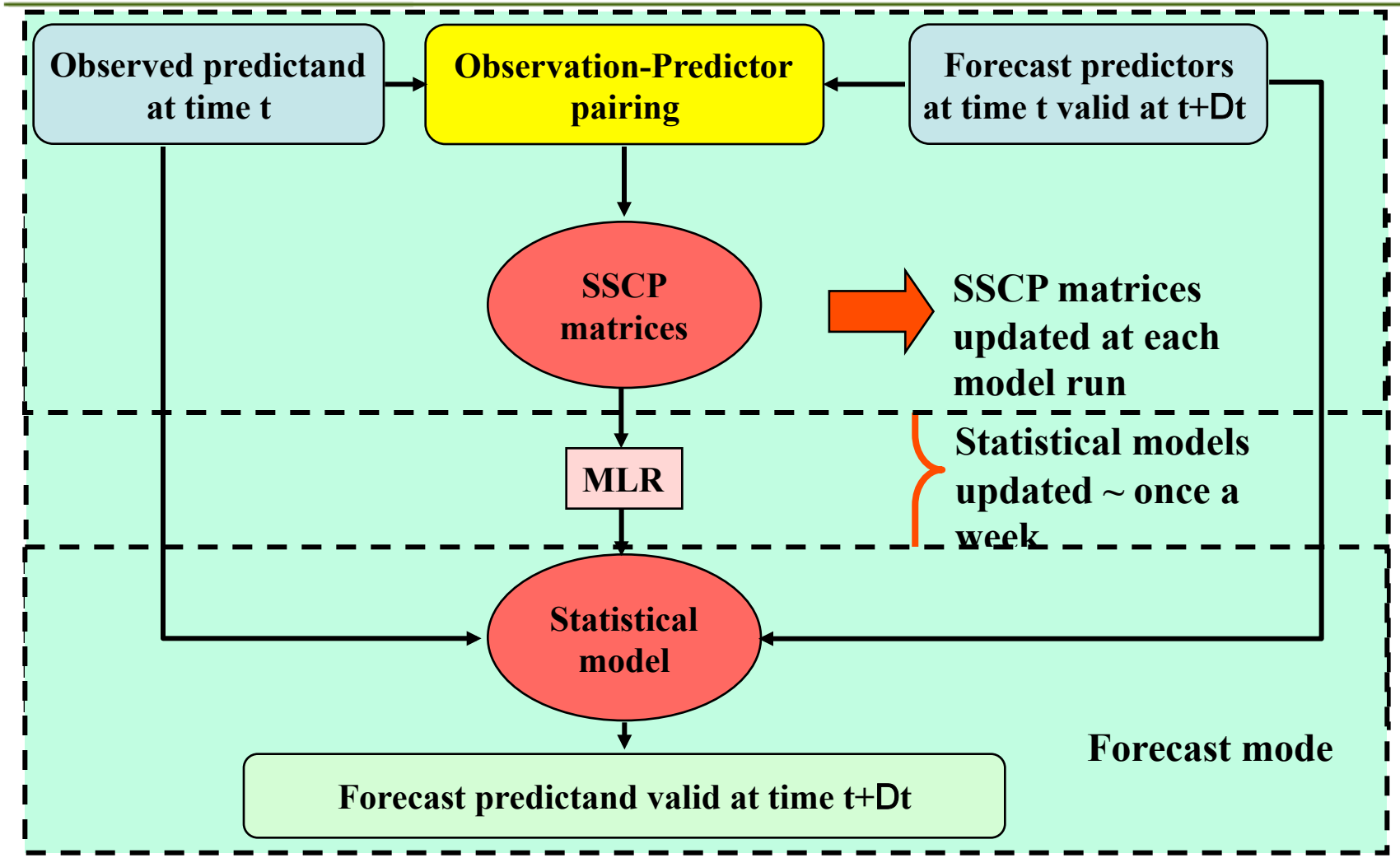
- **UMOS is a post-processing system that utilizes the model's predictors and can follow its evolution (Updatable MOS).**

- **In operational status at CMC since 1995 for meteorological predictands (TT, POP6, POP12, Wind speed and direction, Cloud Opacity)**

UMOS-AQ overview

- Based on the UMOS for weather elements but using different driving models, predictors, predictands and observation sets.
- Equations are recalculated once a week.
- Model dependent: Equations must be recalculated for every model change.
- Two types of statistics can be used: MLR (Multivariate Linear Regression) and MDA (Multiple Discriminant Analysis).

UMOS mechanism overview



Project history and details

Version 1 (CHRONOS + GEM Regional)

- Two predictands: [O3], [PM25], later added [NO2] – **3-hourly forecasts**
- Air quality model: CHRONOS
- Two daily runs (00Z and 12Z)
- T+48hrs forecast
- Database: 3+ years (2006, 2007, 2008, 2009)

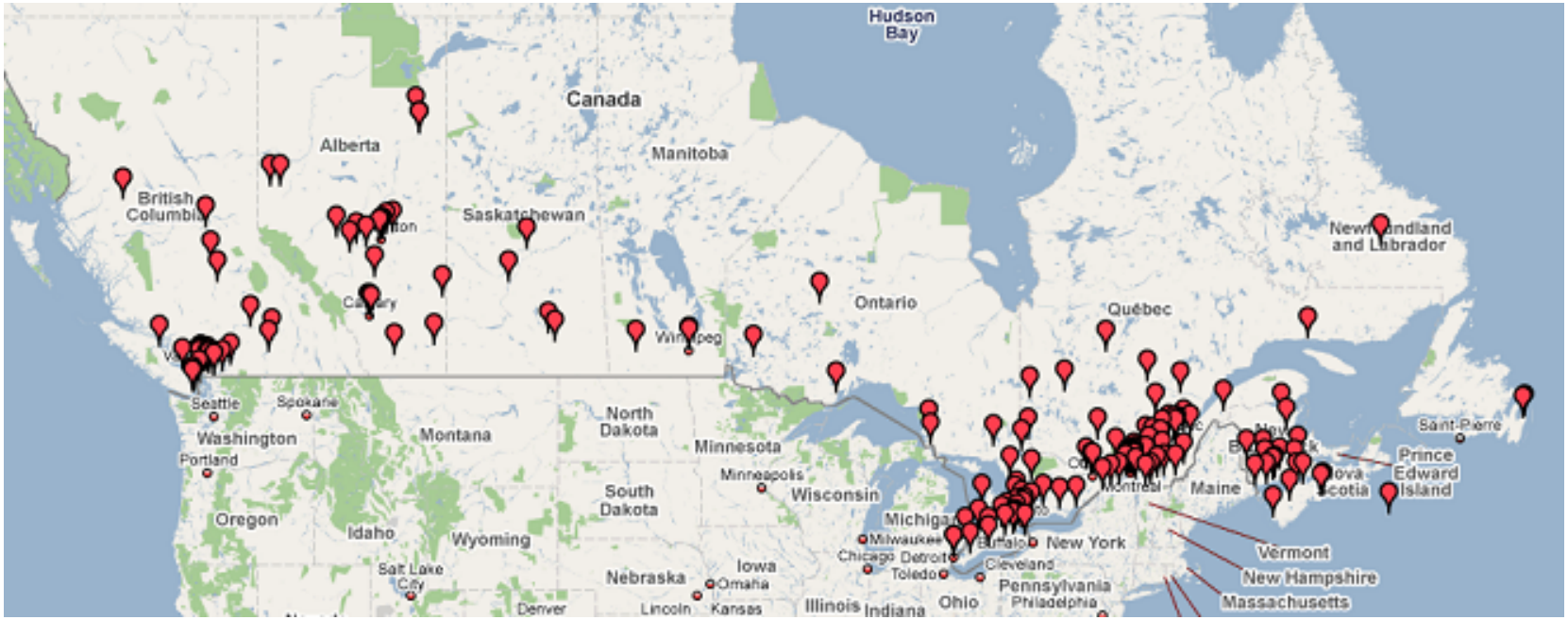
Version 2 (GEM-MACH15)

- Three predictands: [O3], [PM25] et [NO2]
- Air quality model: GEM-MACH15
- Performed a model switchover on July 2009 with approximately 100 cases of hindcast from the new model (GEM-MACH15)
- Cloned original 3-hourly SSCP matrices to hourly versions in order to make the switch into **hourly forecasts**

Observation sites

Total stations in UMOS-AQ Dictionary: **231**

- O3 is hourly reported by ~ **175** stations
- PM25 is hourly reported by ~ **160** stations
- NO2 is hourly reported by ~ **120** stations
- All three pollutants (AQHI): ~ **80** stations



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Predictors

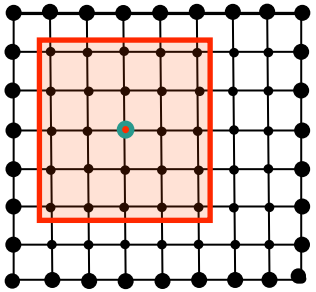
Total of 84 predictors in 3 main categories:

- Meteorological:

UU, VV, HR, GZ, ES, Calculated Mixing Height, … @ (sfc, 925mb, 850mb,700mb, hybrid levels…) etc.

- Chemical:

O3, NO2, PM25 @ SFC, Max and Avg values over the lower vertical levels (~500m) and "neighbor sampling" (n=2)



- Time related:

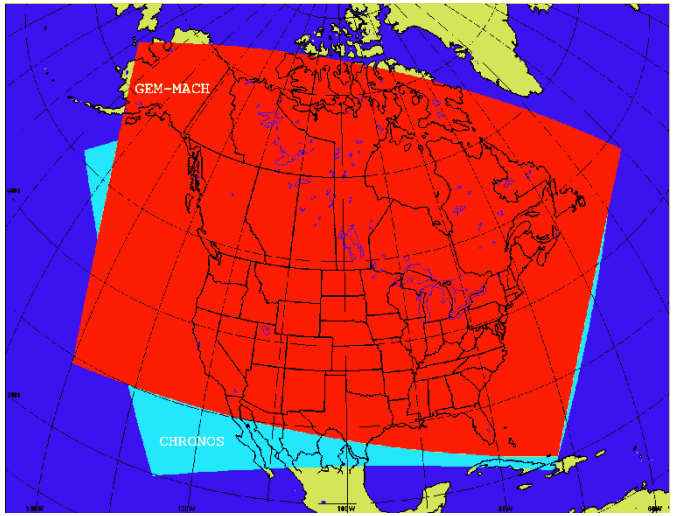
Sine of Julian Day, Day of week, etc.

Predictors: equations

- UMOS generates one equation per station, per pollutant, per forecast hour, per run.
- In order to have stable equations we need to accumulate a minimum of 250+ cases.
- We have calibrated the system so that on average there are 2-4 factors per equation in order to avoid “overfitting”.

CHRONOS vs GEM-MACH15

	CHRONOS	GEM-MACH15
Resolution:	21Km	15km (45% of GEM's grid points)
Time step	3600s (Chemistry)	900s (Chemistry) and 450s (Meteorology)
Chemical Processes	Significant differences between the two models in: Emissions inventory used, Gas and Aqueous-Phase Chemistry, Aerosol dynamics, Boundary conditions, etc.	
Vertical Levels	24 Gal-Chen levels up to 6km	58 Hybrid levels up to ~50km (0.1hPa)
Meteorology	Interpolated from GEM15	Own Physics and Dynamic packages – almost identical to GEM15
Emission fields	2000 (Can) – 2001 (US) (corrected for 2005 regulations)	2005 (US) and 2006(Can)



(Courtesy: David Anselmo, AQMAS)

- CHRONOS is an 'off-line' model
- In general GEM-MACH15 performs better
- **<u>Important</u> : From a statistical point of view, the two models have different characteristics.**

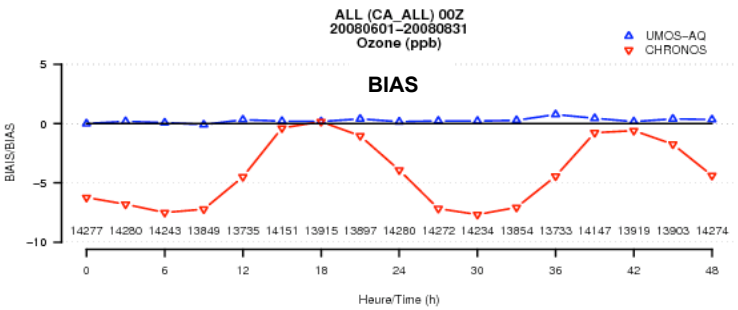
Verifications

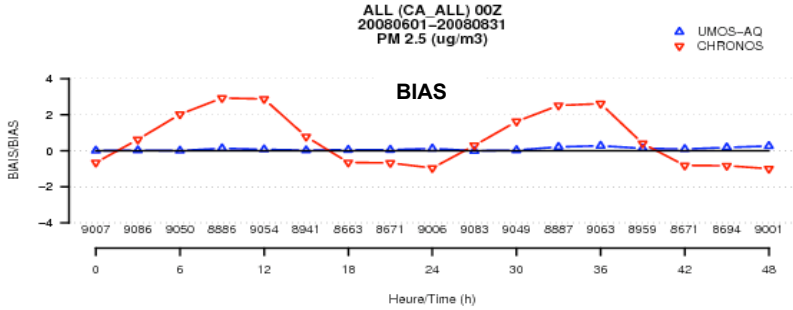
1) <u>Version 1b – CHRONOS: [O3], [PM25], [NO2], 3-hourly forecasts – All stations</u> :
Summer (90 days): 1st June 2008 – 31st August 2008, 00Z (pseudo-operational mode)
Winter (90 days): 1st December 2008 – 28th February 2009, 00Z (pseudo-operational mode)

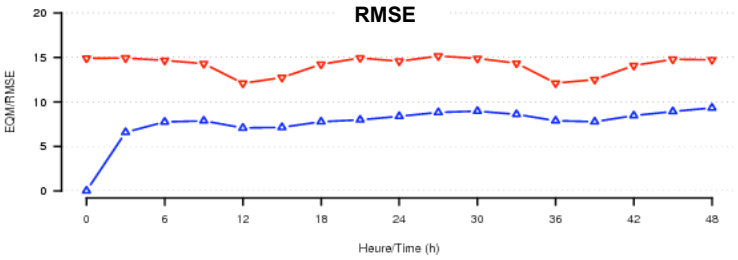
2) <u>Version 2 – GEM-MACH15: [O3], [PM25], [NO2], hourly forecasts</u>:
Summer (60 days): 1st August 2009 – 1st October 2009 (pseudo-operational mode)

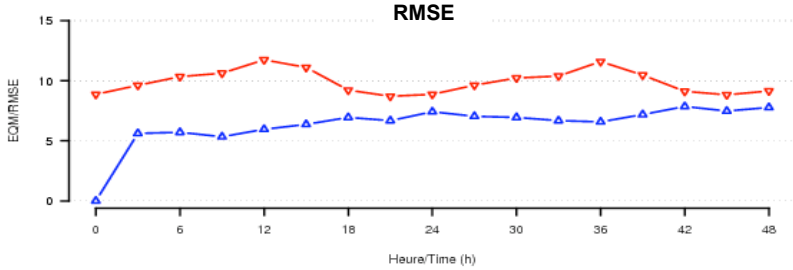
- **Data are based on independent samples**

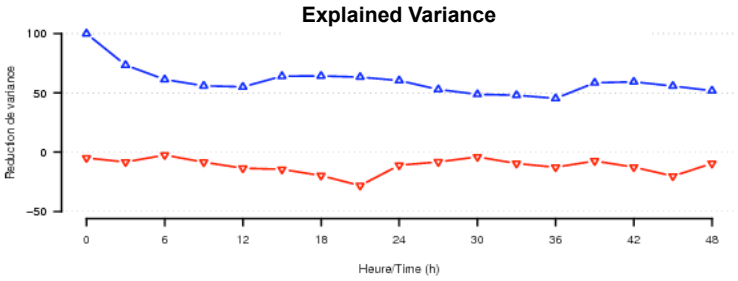
Verifications1: Summer, 00Z, 90 days [20080601,20080831] : Pseudo-operational mode CHRONOS (O3 and PM25)

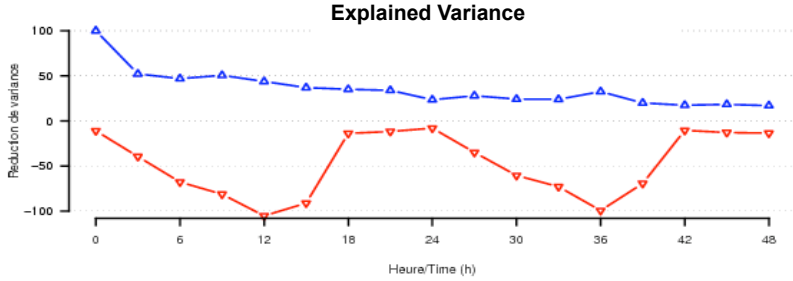




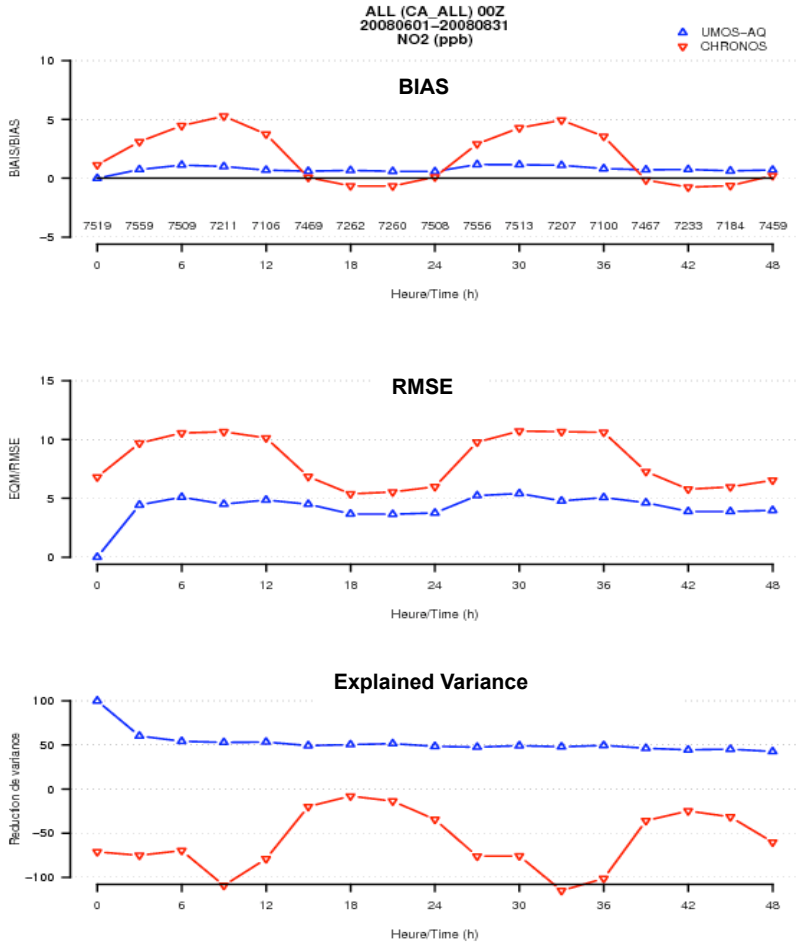




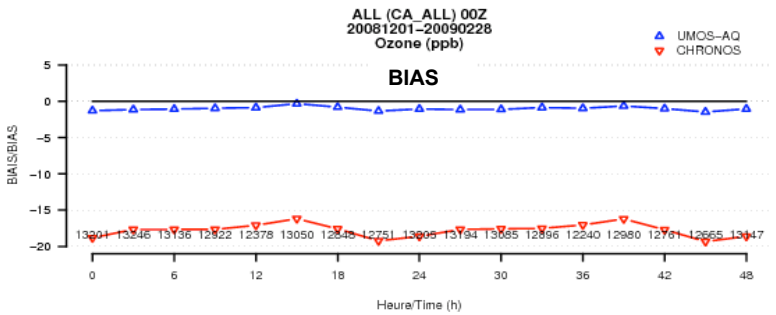


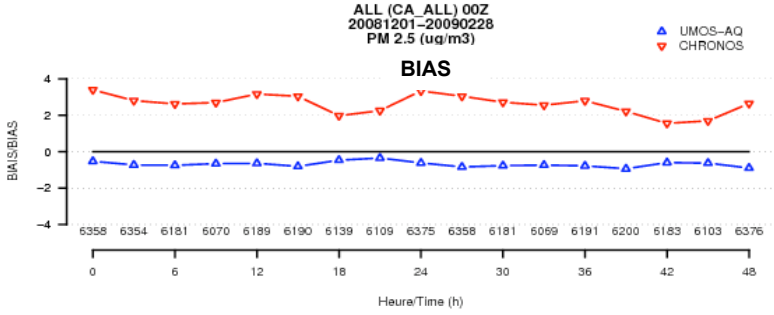


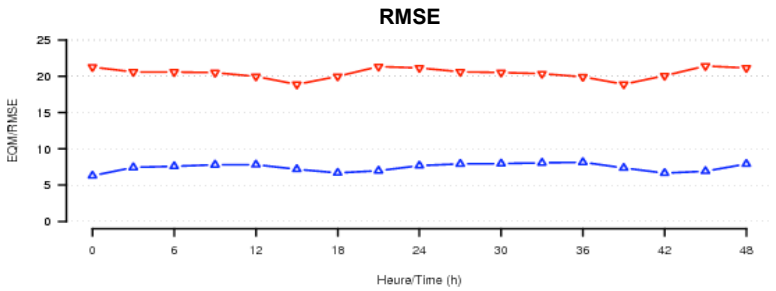
Verifications1: Summer, 00Z, 90 days [20080601,20080831] : Pseudo-operational mode CHRONOS (NO2)

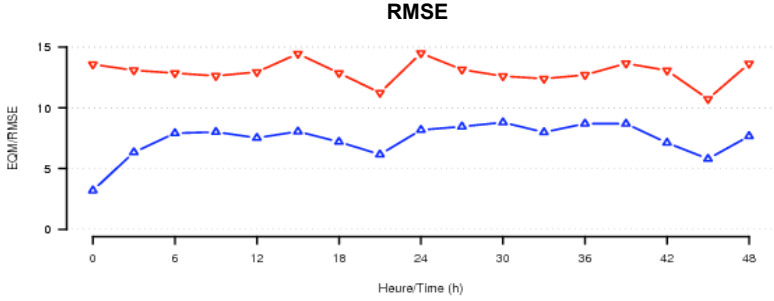


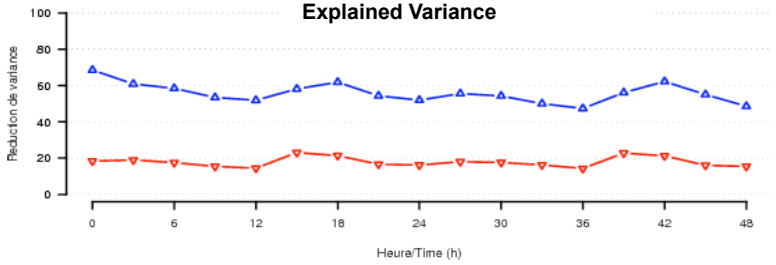
Verifications1: Winter, 00Z, 90 days [20081201,20090228] : Pseudo-operational mode CHRONOS (O3 and PM25)

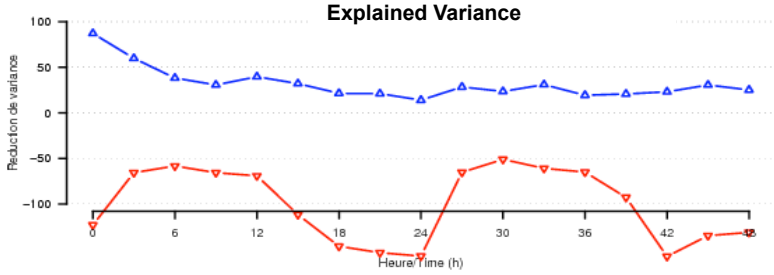




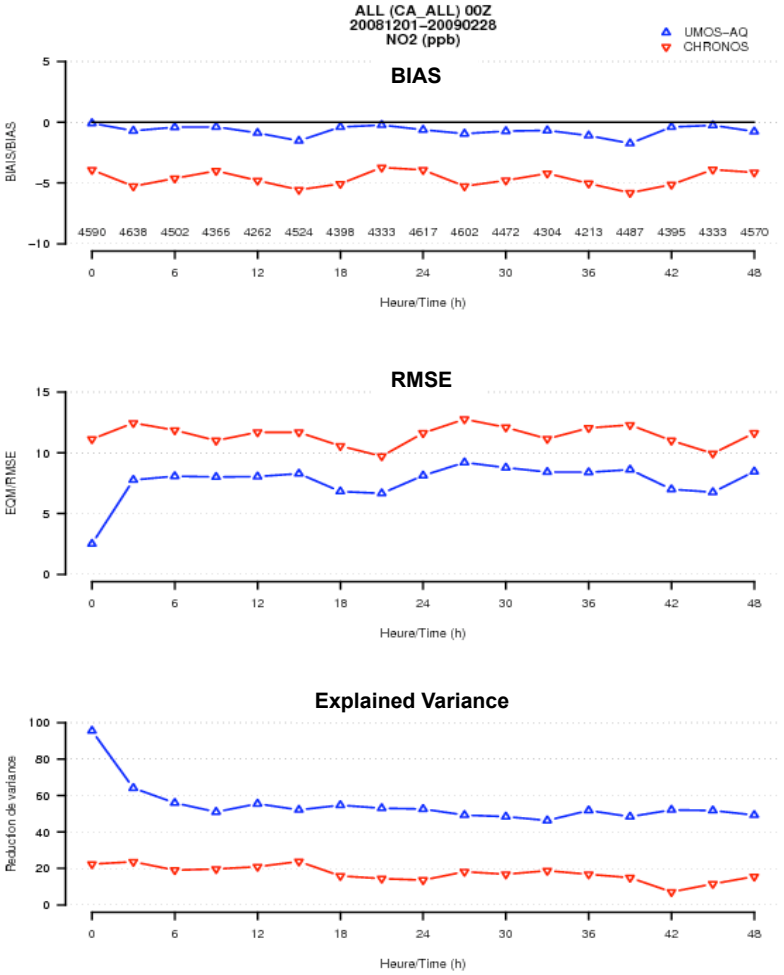




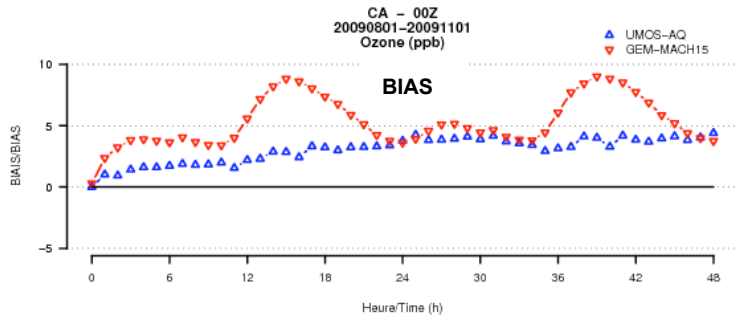


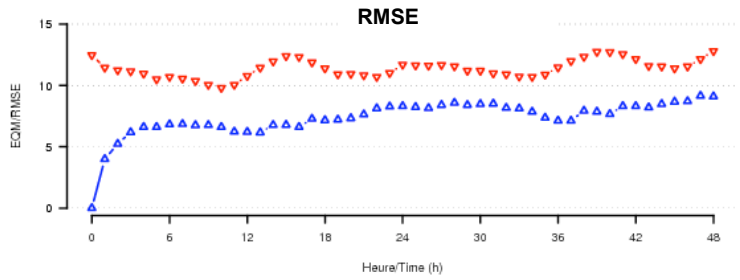


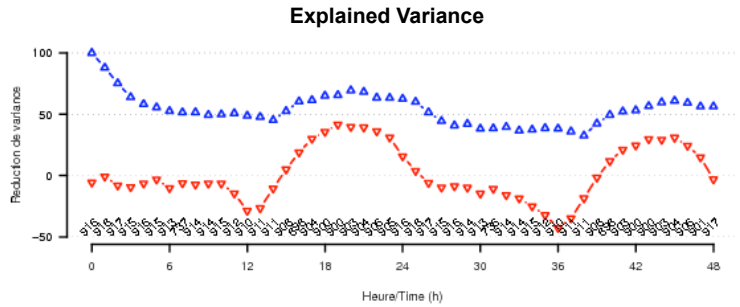
Verifications1: Winter, 00Z, 90 days [20081201,20090228] : Pseudo-operational mode CHRONOS (NO2)

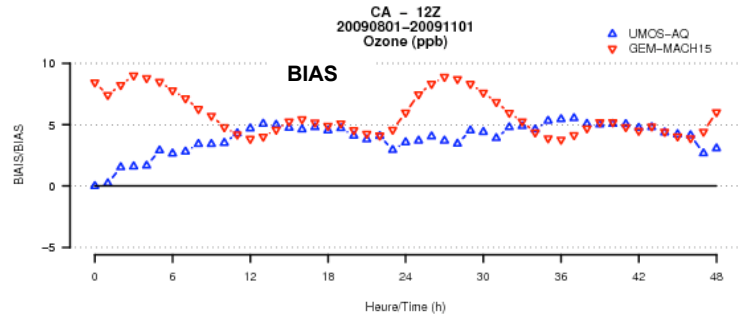


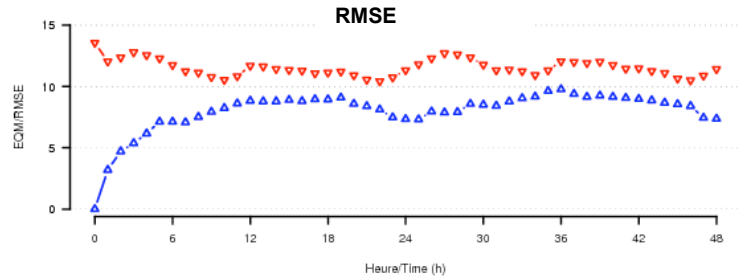
Verifications2: [O3]:Summer, 65 days [20090801,20091001] : pseudo-operational mode GEM-MACH15

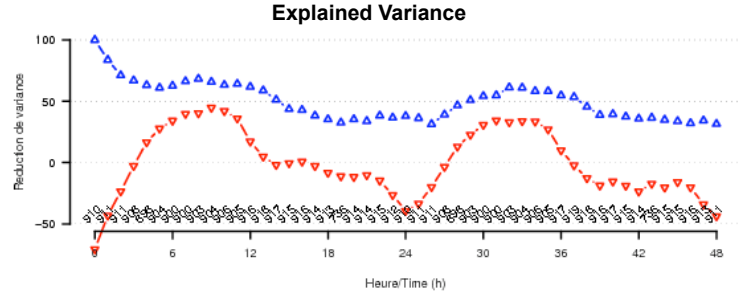












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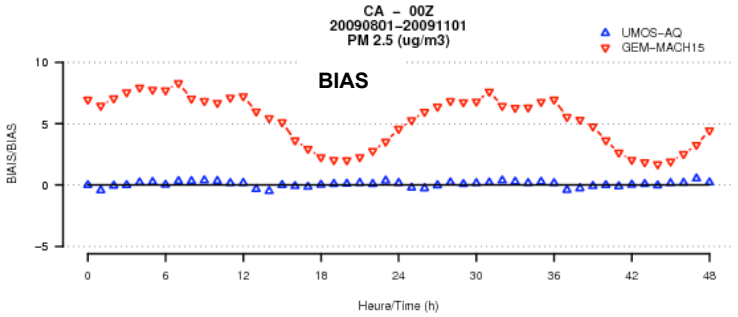

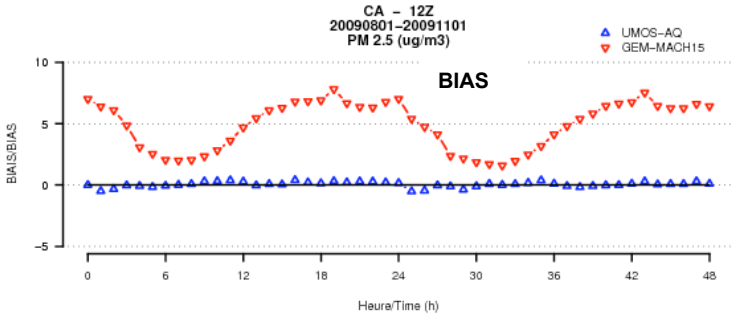

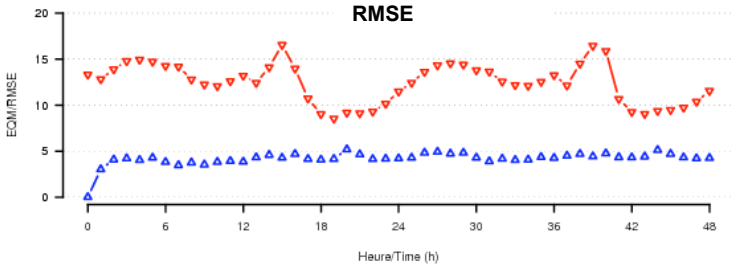

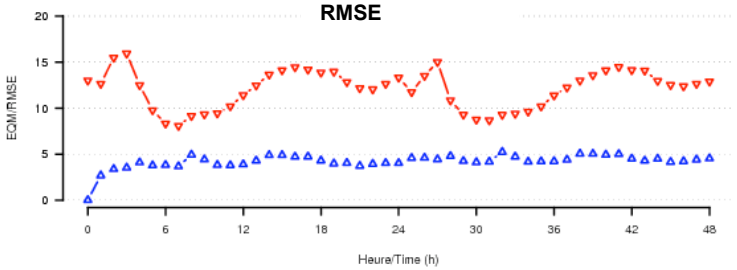

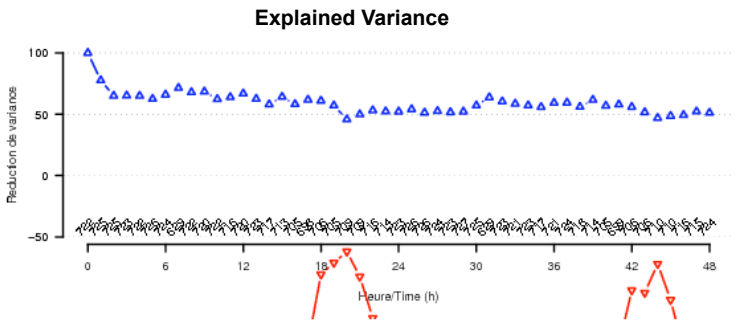

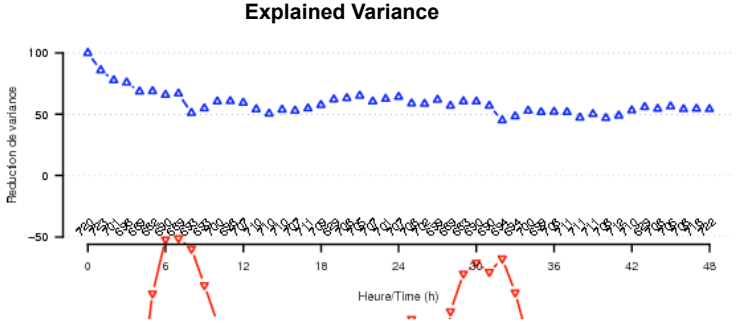

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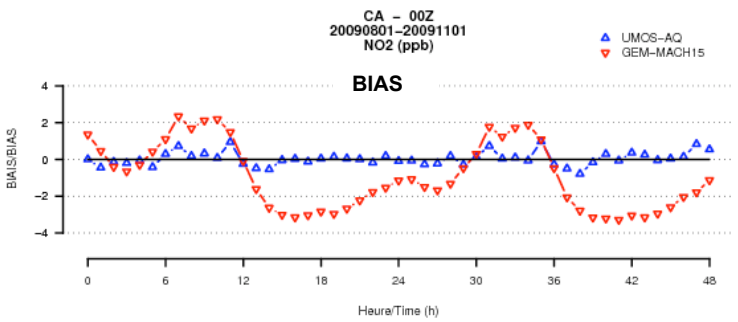
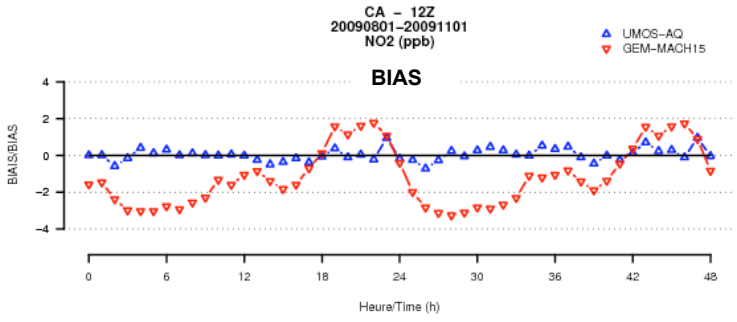
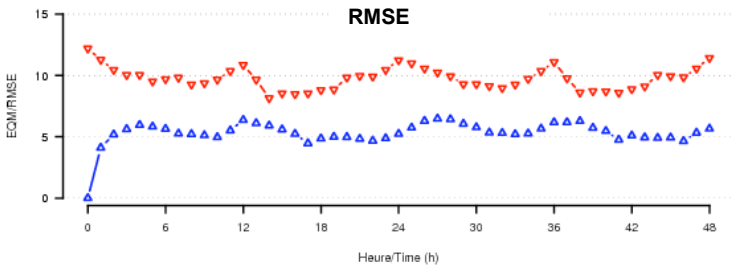
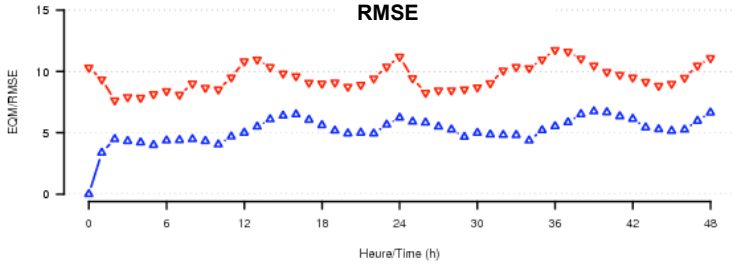
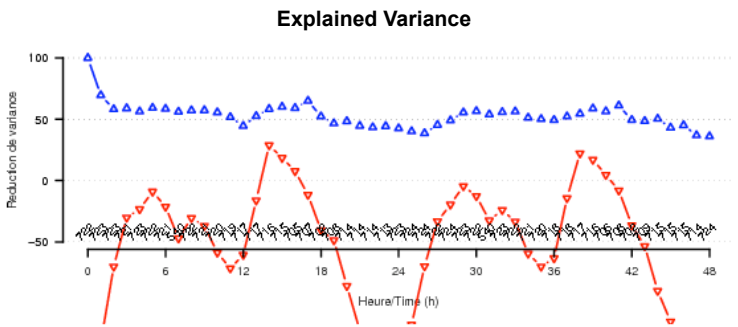
Verifications2: [NO2]:Summer, 00Z, 65 days [20090801,20091001] : pseudo-operational mode GEM-MACH15

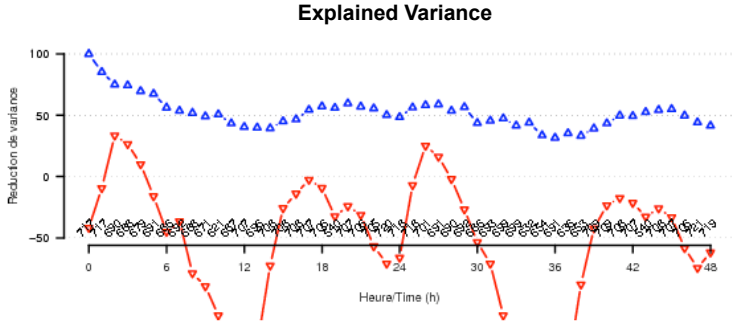












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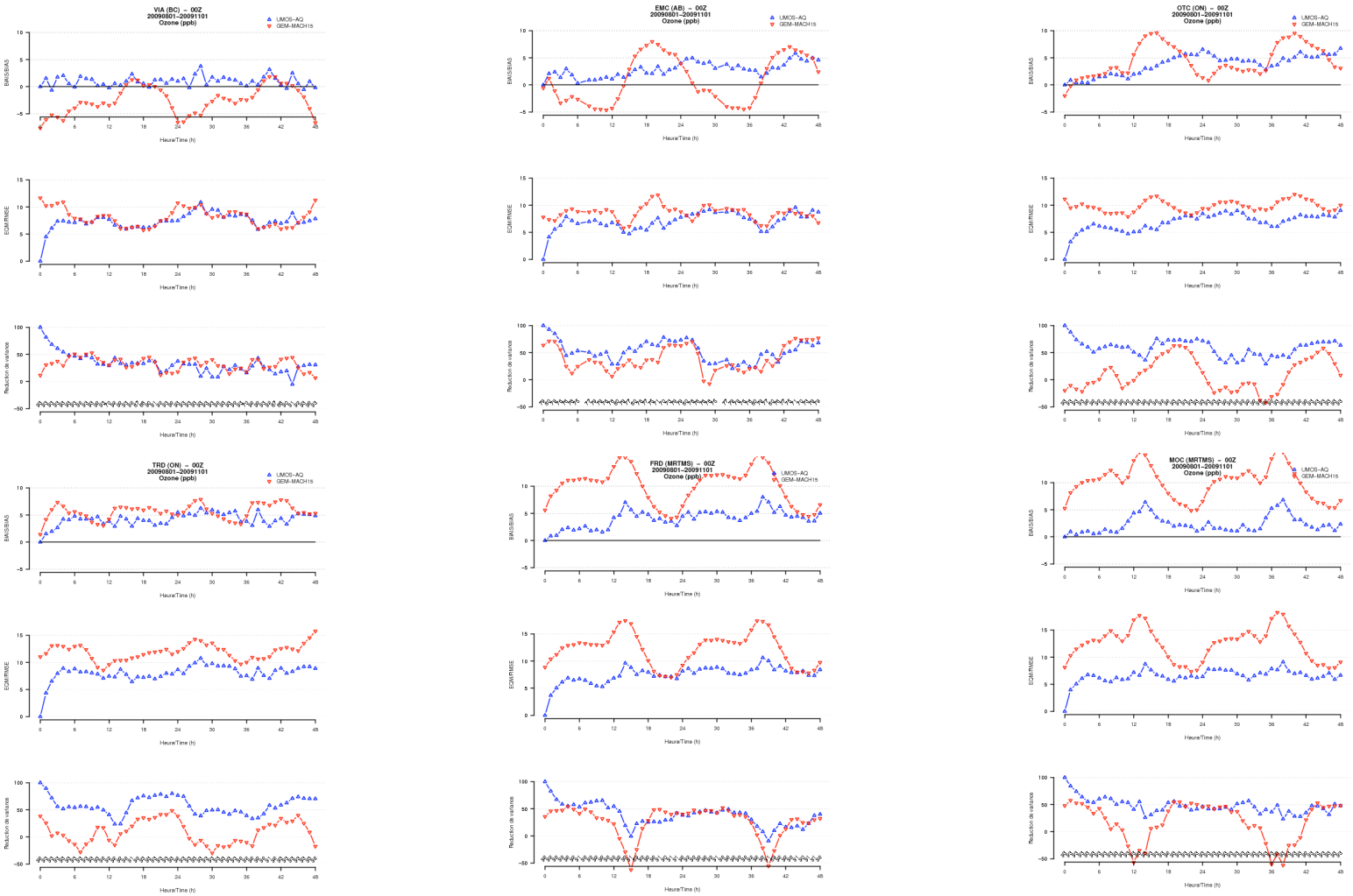
Verifications2: [O3]:Summer, 00Z, 65 days [20090801,20091001] : pseudo-operational mode GEM-MACH15 (Various stations)



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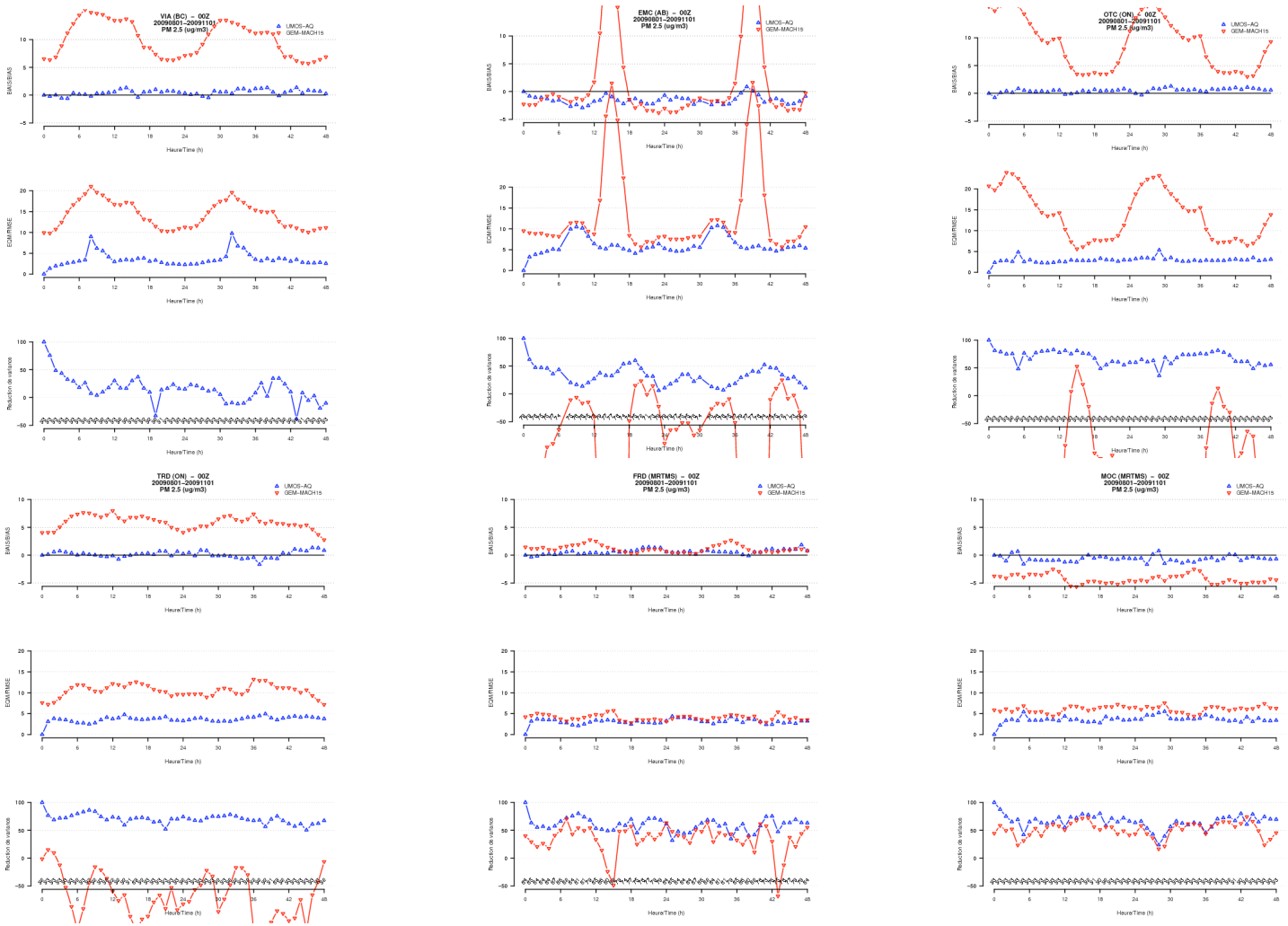
GEM-MACH15 (Various stations)



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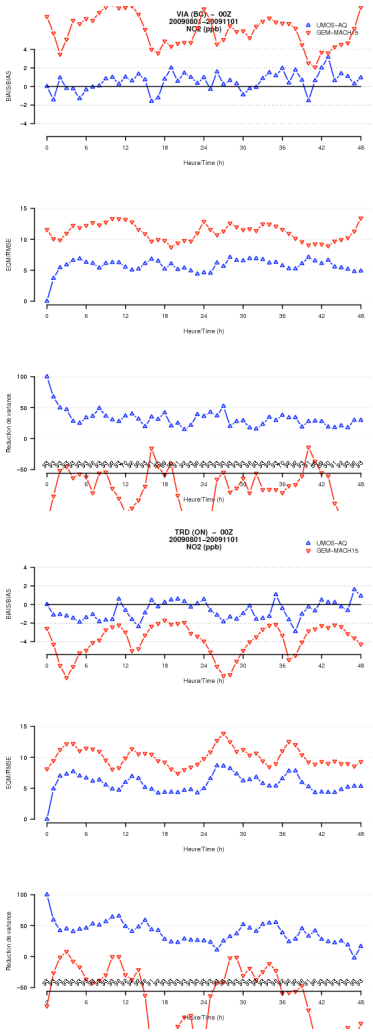
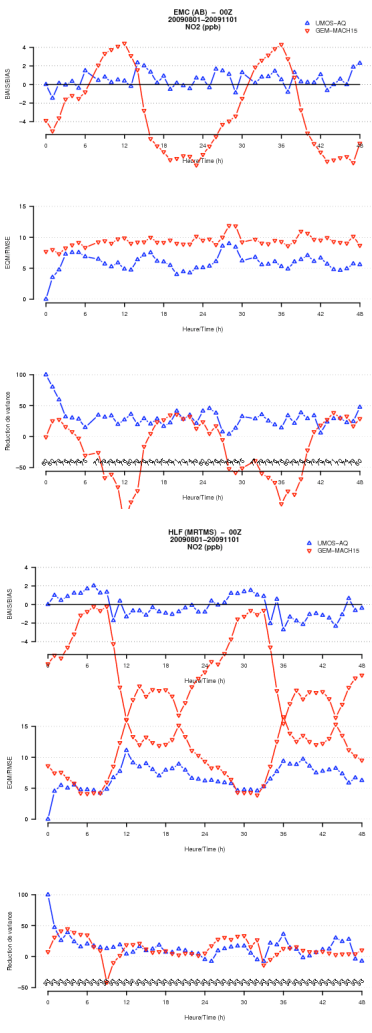
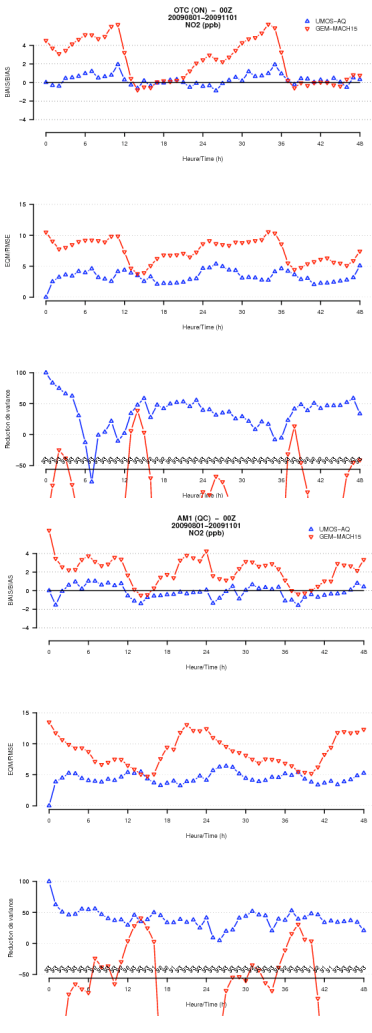






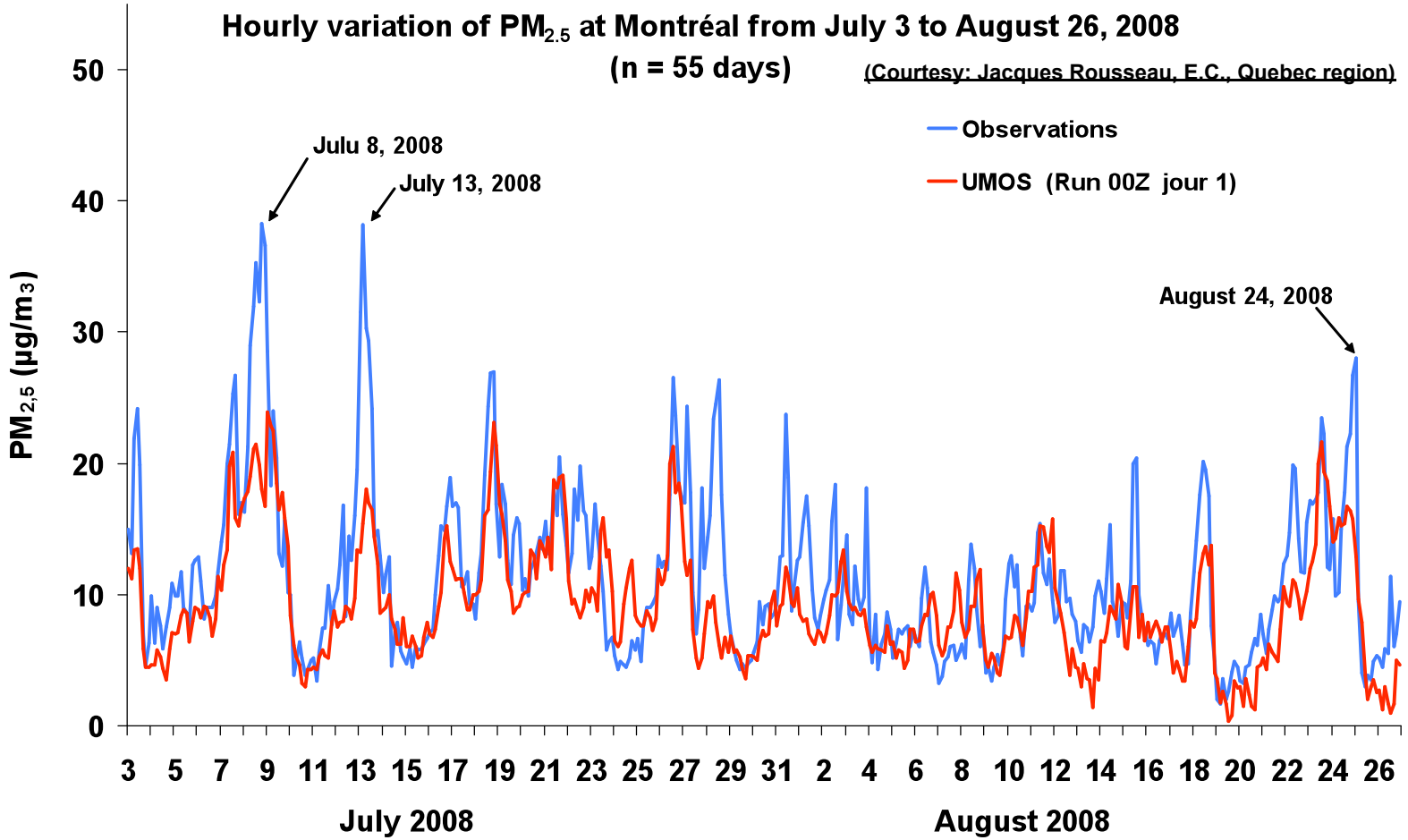
Verifications: Conclusions

- In the vast majority of forecast hours, over all stations:
  - ✓ The model's bias is significantly removed.
  - ✓ RMSE is reduced.
  - ✓ More than the above, we explain better the observed variance. Better skill.
- **<u>UMOS-AQ significantly improves the model's forecast quality.</u>**

Forecasting extreme events (episodes)

- MLR (linear) techniques tend to “push” the forecast towards a mean value therefore making extreme event forecasting more challenging.
- We want to study the model’s and UMOS-AQ behaviour during episodes. Difficult to acquire extensive training data: percentage of episodes compared to “average” values is small.
- MDA approach could be more skilful in episode forecasting.

Example: Summer 2008 Montreal



AQ model sensitivity experiment

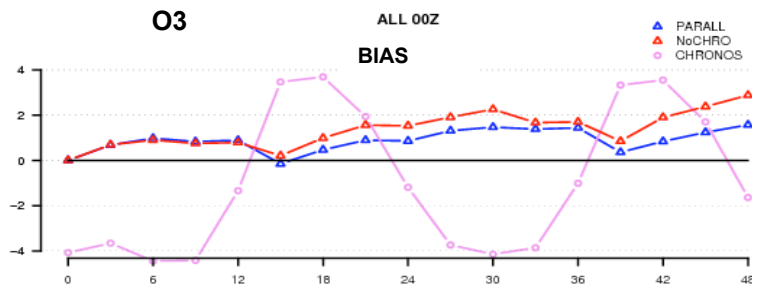
In an attempt to understand the AQ model's contribution we compared forecasts created with and without the CHRONOS predictors.

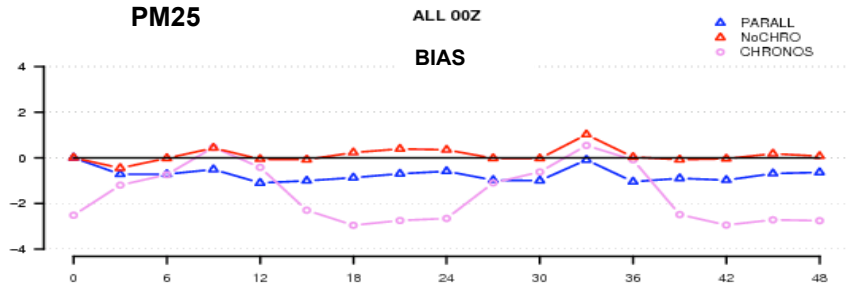
The results were separated and compared over two different independent periods:

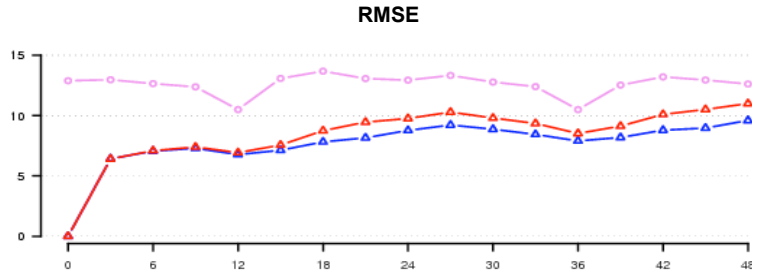
1. **Summer: June 1 to August 31, 2008**
2. **Winter: January 1, 2008 to February 15, 2008**

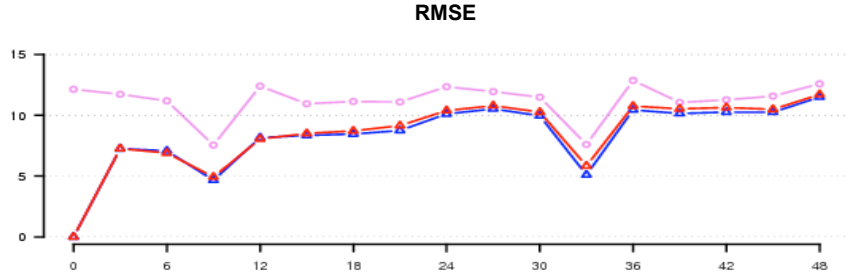
Sensitivity experiment verifications :

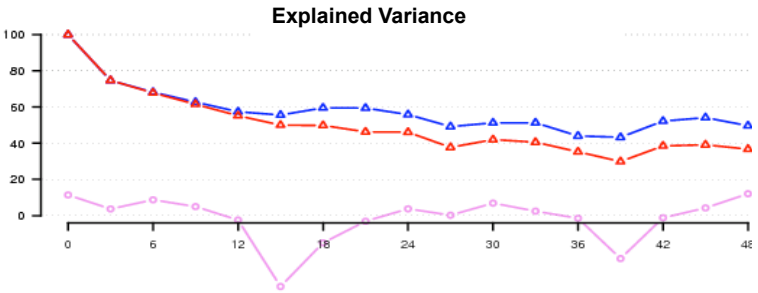
Summer 2008: June 1st – August 31st 2008 (O3, PM25)

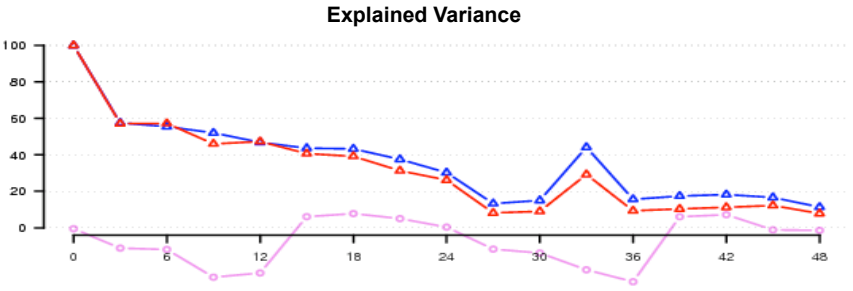






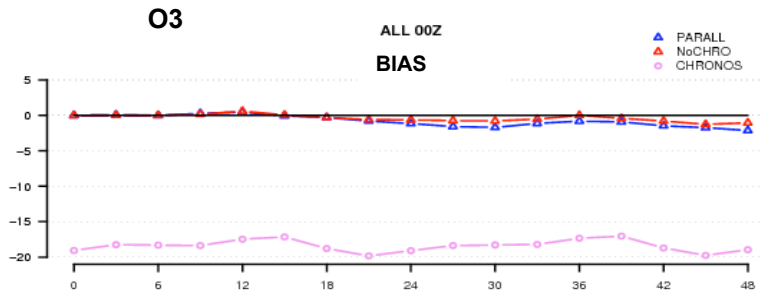


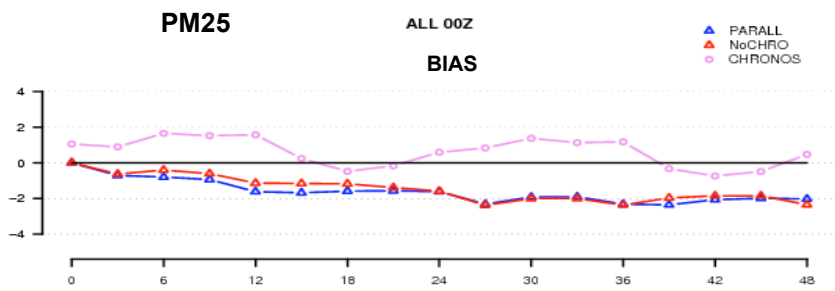


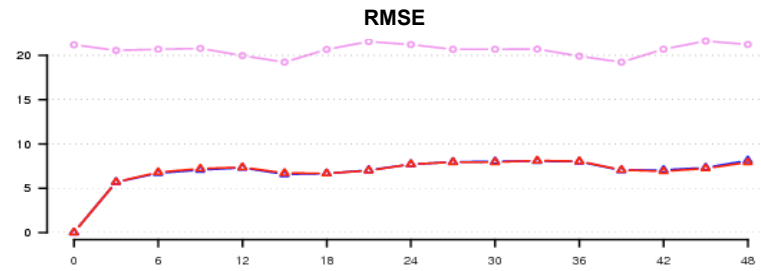


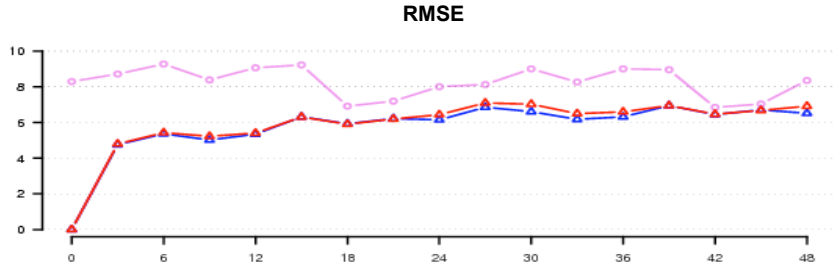
Sensitivity experiment verifications :

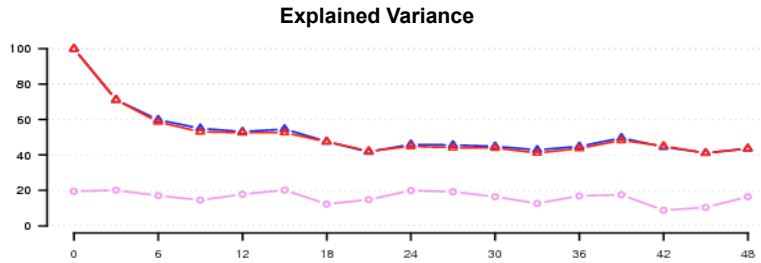
Winter 2008: January 1st – February 15th 2008 (O3, PM25)

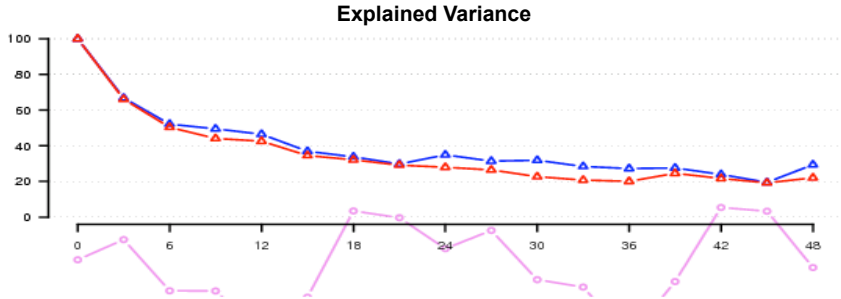












Conclusions

- Over the last 2 years UMOS-AQ has shown a significant improvement over the direct model output for all three pollutants in both seasons. This fact has been repeatedly shown over long and short term independent verification periods.
- An abrupt model switchover along with a matrix cloning operation did not noticeably affect the quality of the forecasts which shows a relative stability of the system.
- UMOS-AQ can provide a high quality national guidance in AQ forecasting.
- Forecasting episodes remains challenging, however future improvement is expected as more cases get accumulated and a full transition to GEM-MACH15 is completed.

Future

- Steps are taken for a possible operational implementation.
- Perform a *predictor-reduction* experiment in order to reduce the number of predictors and simplify the system without loss in the forecast quality.
- Possibility to generalize the forecasts by using MIST (Optimal interpolation tool) in order to produce forecast fields from irregular forecast points.
- MDA will also be evaluated.

Thank you !

Questions ? – Comments ?

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