SYNOP verification of the inconsistencies ("hacks") present in COSMO for the microphysics tracers

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Introduction

In the present COSMO code (COSMO 5.0), the treatment of the microphysics tracers (qv, qc, qi, qr, qs, qg) is not consistent. These inconsistencies existed in previous COSMO versions but have been revealed during the introduction of the new tracer module (*Roches and Fuhrer, 2012*). In principle it is highly desirable to treat all tracers alike, since this simplifies both the code and allows the user to better understand how the tracers are being treated in the model code and where potential problems might stem from. Since many of these "inconsistencies" for the microphysical water species have arisen historically, the reasons for their introduction and their importance for the current code version and implementations at the national weather services are often not known. Thanks to the tracer module and the associated metadata functionality provided by this development, the inconsistencies could be expressed clearly in the code (currently named "hacks") and are also easy to switch on and off. The current implementation in COSMO 5.0 replicates the inconsistencies as they were in previous code versions. The inconsistencies are described in detail in section 3.1.3 of *Roches and Fuhrer, 2012*.

Here, we aim at assessing the relevance of these inconsistencies in terms of model performance for an extended time period and remove some of them if possible to ensure better consistency in the tracer treatment and a more user-friendly COSMO model.

Experiment description

We have performed a standard surface verification (SYNOP) over a 3 months period for a set of simulations using the standard verification package of MeteoSwiss (MOVERO). The verification period is from **13th of May 2013 at 12 UTC to 14th of August 2013 at 00 UTC**. The set of simulations comprises a reference simulation (operational COSMO-7) and a set of experiment simulations running in parallel.

The **reference** simulation (denoted as **OPR**) is done with the code version and the configuration used currently at MeteoSwiss for the **operational runs of COSMO-7**. The code version is based on **COSMO 4.19** and the summary of the namelists used (YUSPECIF) is provided as separated file to this document.

The **experiment** simulations are performed with the same input data and the same configuration (same YUSPECIF) a part from the changes described below. The code version used is **COSMO 4.27** (pre-release of COSMO 5.0 that was available in May 2013). The experiments are:

- **WHR** Same configuration as the operational
- **NHR** Same configuration as the operational but removing all the inconsistencies ("hacks") related to the Runge-Kutta dynamical core
- **WHL** Same configuration as the operational but using the Leapfrog core
- **2HL** Same configuration as the operational but using the Leapfrog dynamical core and removing all the inconsistencies ("hacks") related to the Leapfrog core except for two. The two inconsistencies kept are `SP_ADV_LF` and `MASSFLX_CLP` (see section 3.1.3 of *Roches and Fuhrer, 2012*).

In the next section, the verification results obtained for the 4 experiments and the reference are described.

The tested parameters are PS (Station pressure at barometer height), PMSL (Pressure reduced to mean sea level), T_2M (Temperature at 2 m above ground level), TD_2M (Dew point at 2 m above ground level), DD_10M (Wind direction at 10 m above ground level), FF_10M (Wind speed at 10 m above ground level), CLCT (Total cloud cover), TOT_PREC12 (12-h precipitation sum (06-18 UTC and 18-06 UTC), VMAX_10M (Wind gusts at 10 m above ground level).

The computed scores are:

ME	Mean Error (bias, average difference between model and observation)
MAE	Mean Absolute Error (average difference between model and observation, independent of sign)
STDE	Standard Deviation of Error (variability of error)
RMSE	Root Mean Square Error (error independent of sign, more weight to larger deviations)
COR	Correlation
NOBS	Number of valid observations

For some of the parameters, additional scores are computed:

FBI	Frequency bias
POD	Probability of detection
FAR	False alarm ratio
OF	Observed frequency

Results at a glance

All the scores are shown in Appendix A (total scores) and B (time series of the scores).
The same color code is applied through all plots:

- **Black** Observations
- **Blue** Reference simulation (denoted as **OPR**)
- **Green** Same configuration as the operational (denoted as **WHR**)
- **Red** Same configuration as the operational but removing all the inconsistencies ("hacks") related to the Runge-Kutta core (denoted as **NHR**)
- **Orange** Same configuration as the operational but using the Leapfrog core (denoted as **WHL**)
- **Pink** Same configuration as the operational but using the Leapfrog core and keeping only `SP_ADV_LF` and `MASSFLX_CLP` (denoted as **2HL**)

For the **Runge-Kutta dynamical core, no significant difference** can be observed when comparing the runs with the inconsistencies (green curves) and the runs without the inconsistencies (red curves). This behavior can be observed for all scores. It thus means that the inconsistencies present in the current COSMO code for the Runge-Kutta core have **no (significant) impact on the results**.

For the **Leapfrog core**, the results obtained with all the inconsistencies (orange curves) or with only two of them (pink curves) are **nearly identical**. It means that all remaining inconsistencies have **no (significant) impact on the results**.

An additional experiment has been performed for the Leapfrog core by removing all the inconsistencies related to the Leapfrog core. This experiment was not successful: some significant differences could be observed between the runs with and without inconsistencies (an example is shown in Appendix C but with different color codes). The differences are due to the two inconsistencies mentioned above: **`SP_ADV_LF` and `MASSFLX_CLP`**. It is thus important **to keep** these two inconsistencies in the Leapfrog core to ensure results that are consistent with previous code versions.

Consequences for the COSMO code and proposition for COSMO 5.1

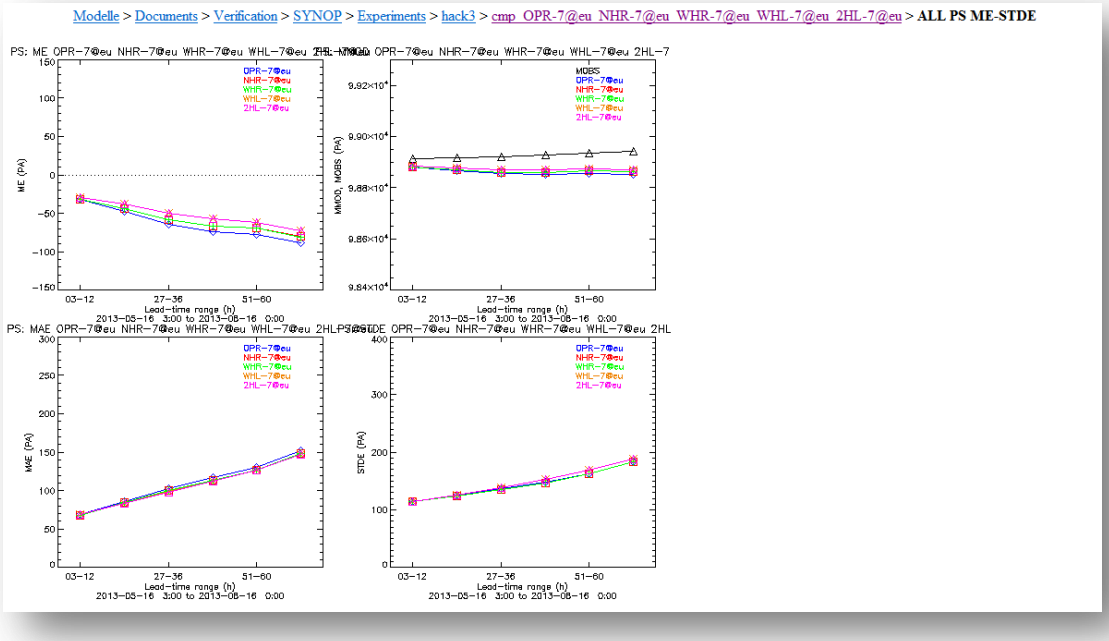
Since all inconsistencies ("hacks") but two (`SP_ADV_LF` and `MASSFLX_CLP`) have no significant impact on the results, we propose to remove all the code parts related to these inconsistencies.
The removal of these inconsistences corresponds to the removal of approximately 750 source code lines in the files organize_physics.f90, src_tracer.f90, slow_tendencies.f90, src_advection_rk.f90,

src_tracer.f90, src_relaxation.f90, src_leapfrog.f90, src_slow_tendencies_rk.f90. It will also simplify the workflow of the model due to the removal of several large `IF`-blocks in the code.

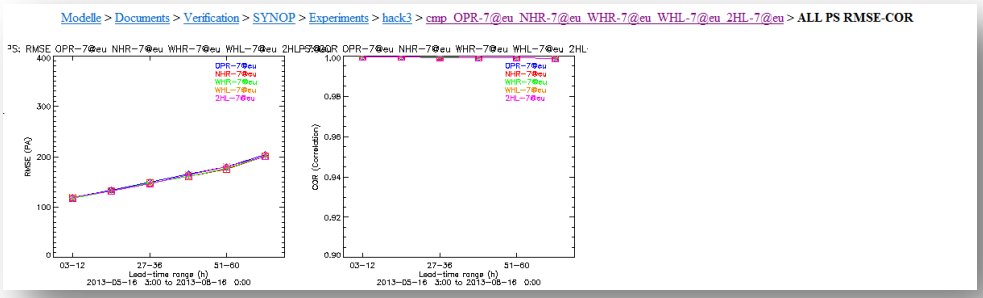
In summary, the proposed modification will remove unnecessary complexity in the code, making it simpler to use and maintain. In case this proposition is supported by the WG2 chair and accepted by the SMC, we can provide a version of COSMO 5.1 without these inconsistencies (“hacks”) to the source code administrator.

Appendix A: Total scores for all lead times

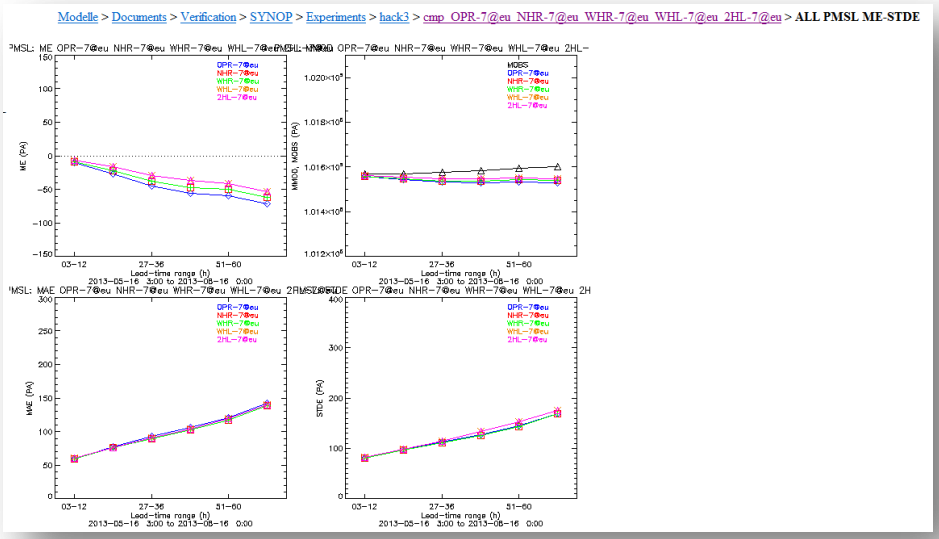
Mean Error for PS



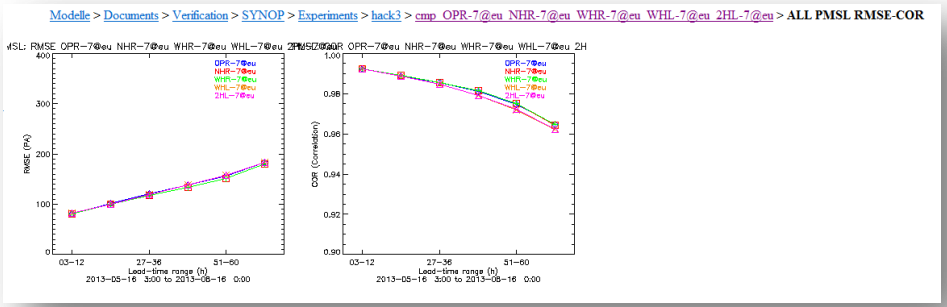
Root mean square error for PS



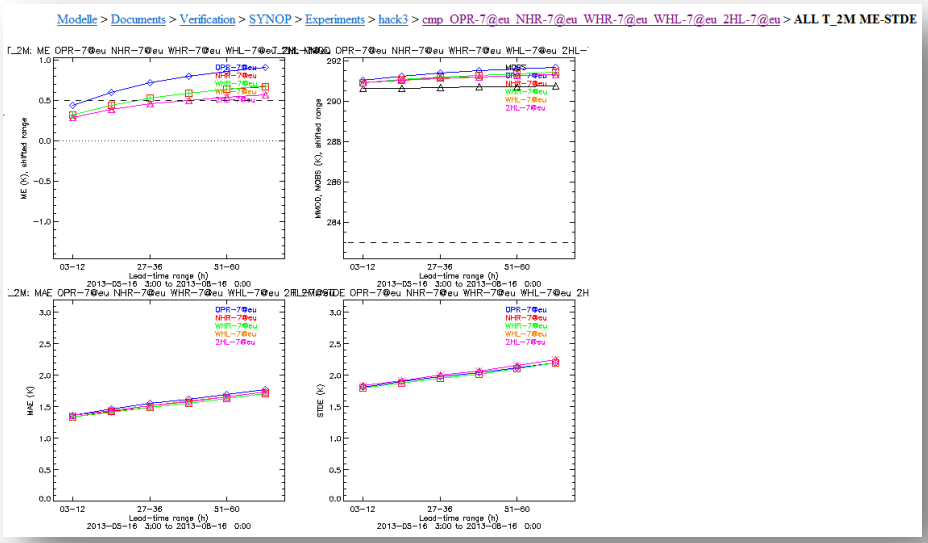
Mean Error for PMSL



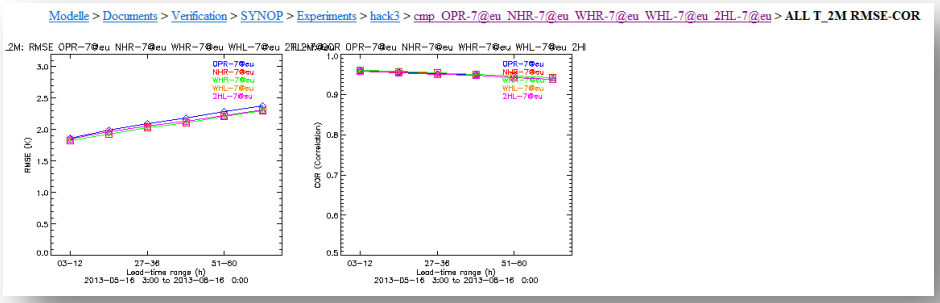
Root mean square error for PMSL



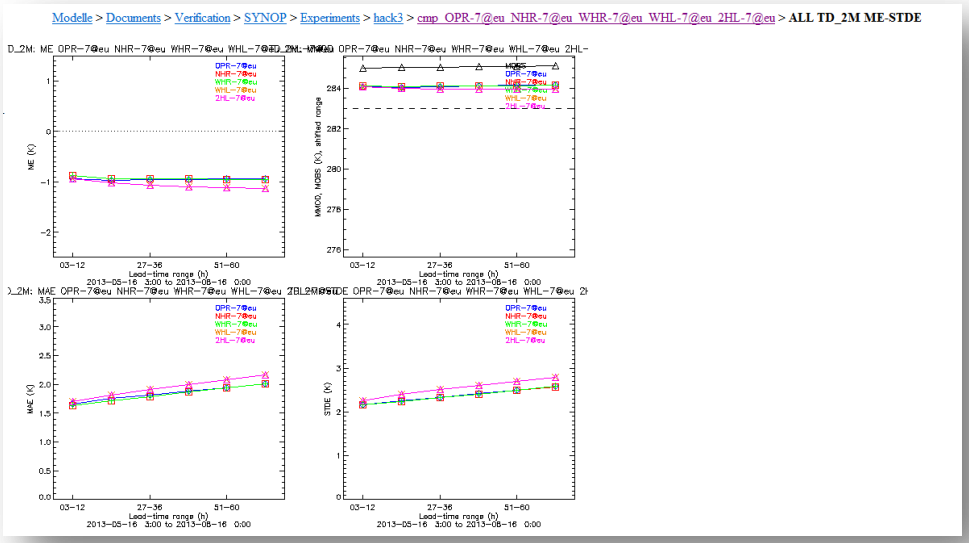
Mean Error for T_2M



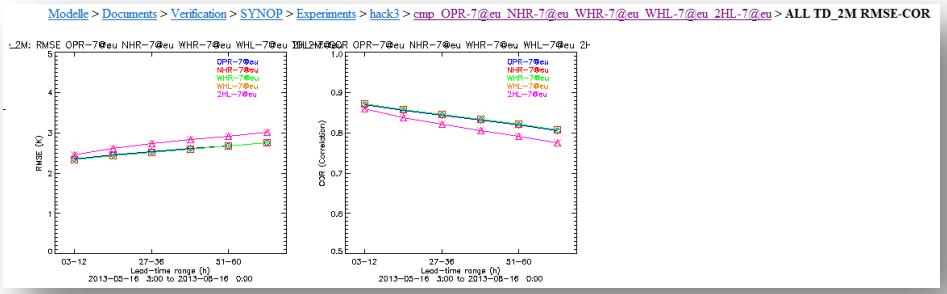
Root mean square error for T_2M



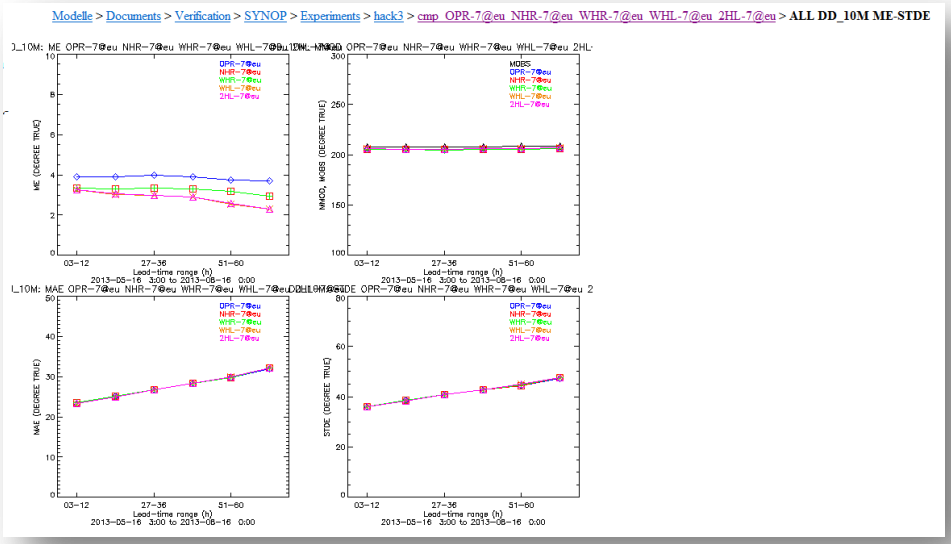
Mean Error for TD_2M



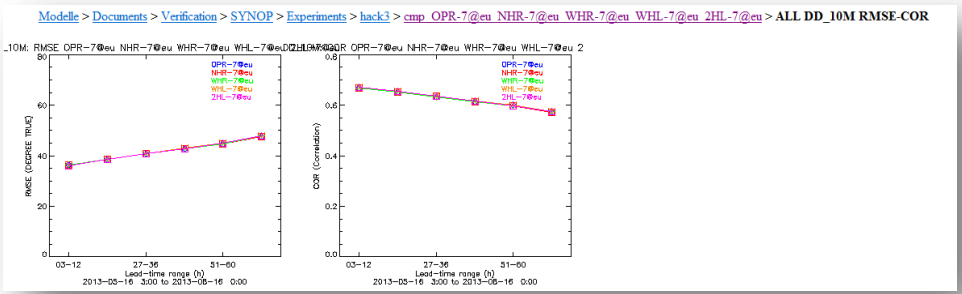
Root mean square error for TD_2M



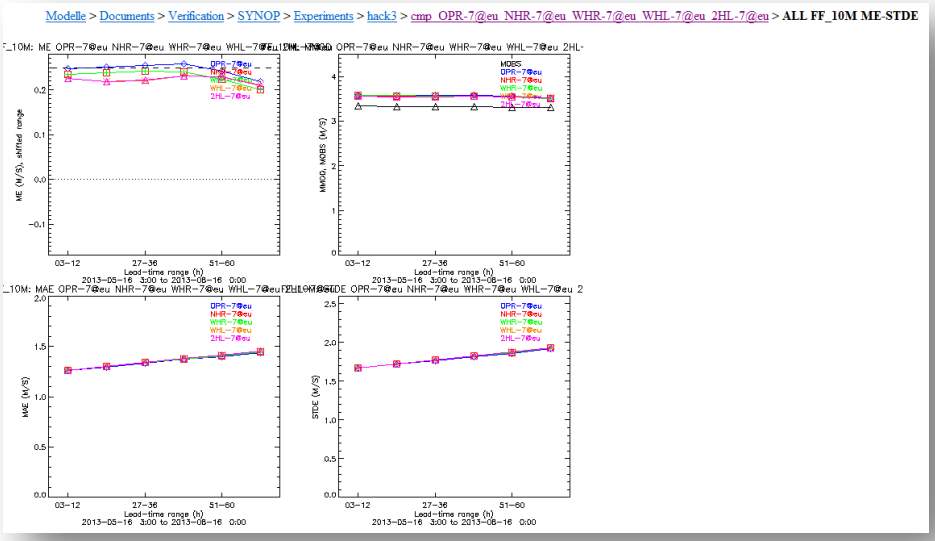
Mean Error for DD_10M



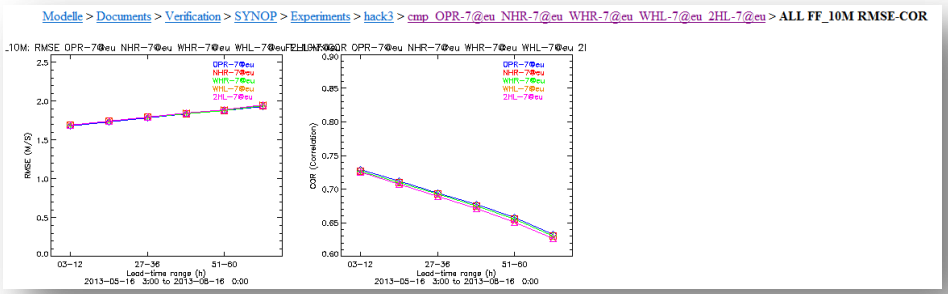
Root mean square error for DD_10M



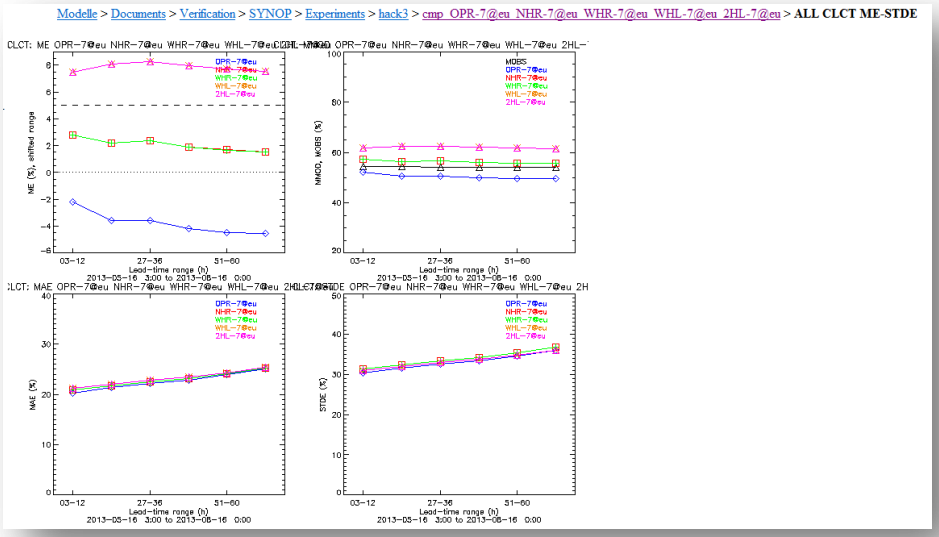
Mean Error for FF_10M



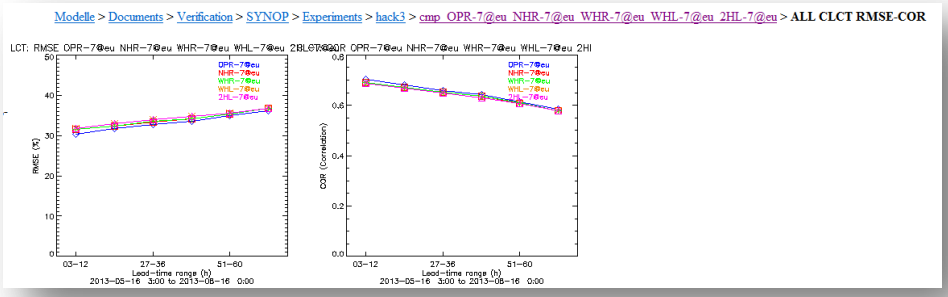
Root mean square error for FF_10M



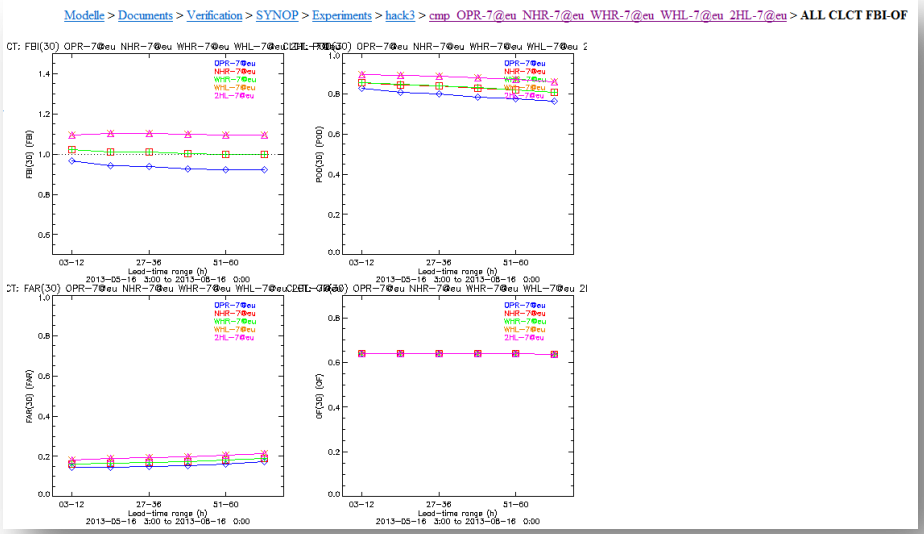
Mean Error for CLCT



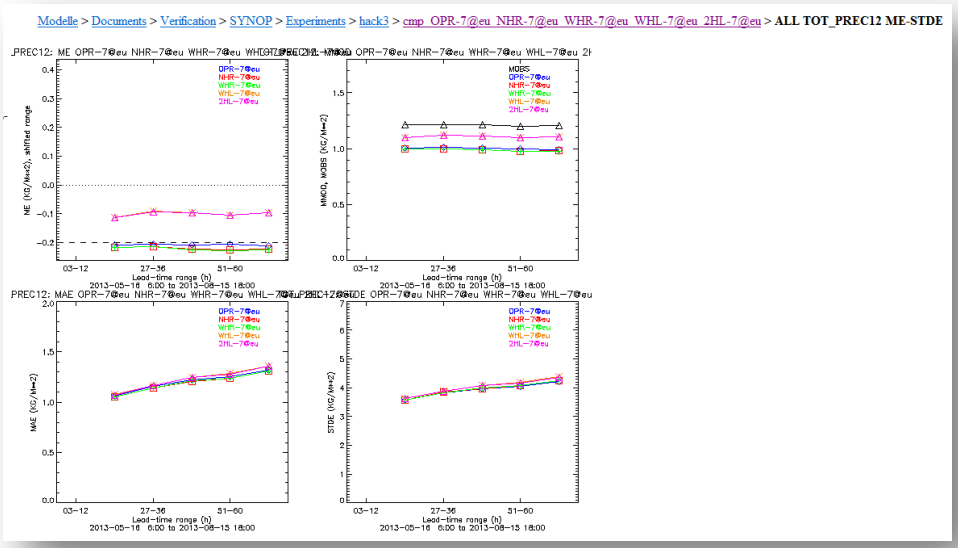
Root mean square error for CLCT



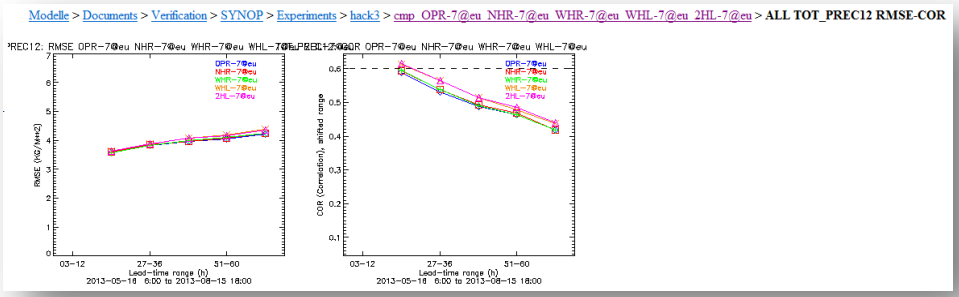
FBI for CLCT



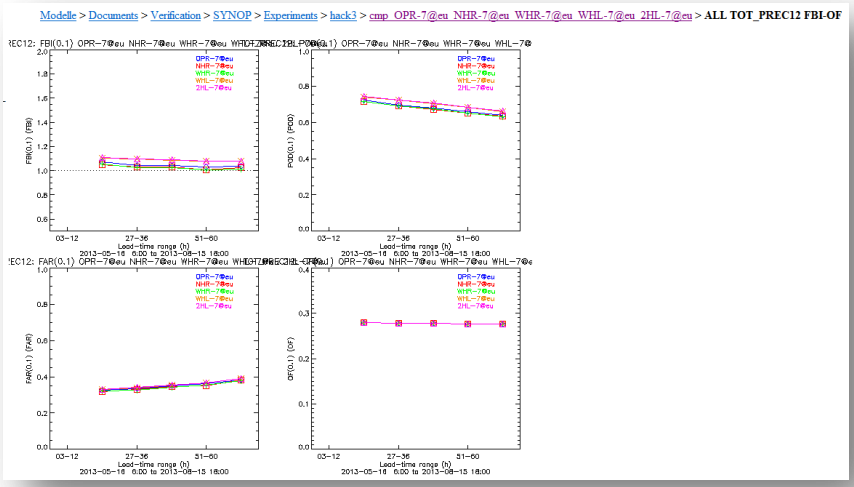
Mean Error for TOT_PREC12



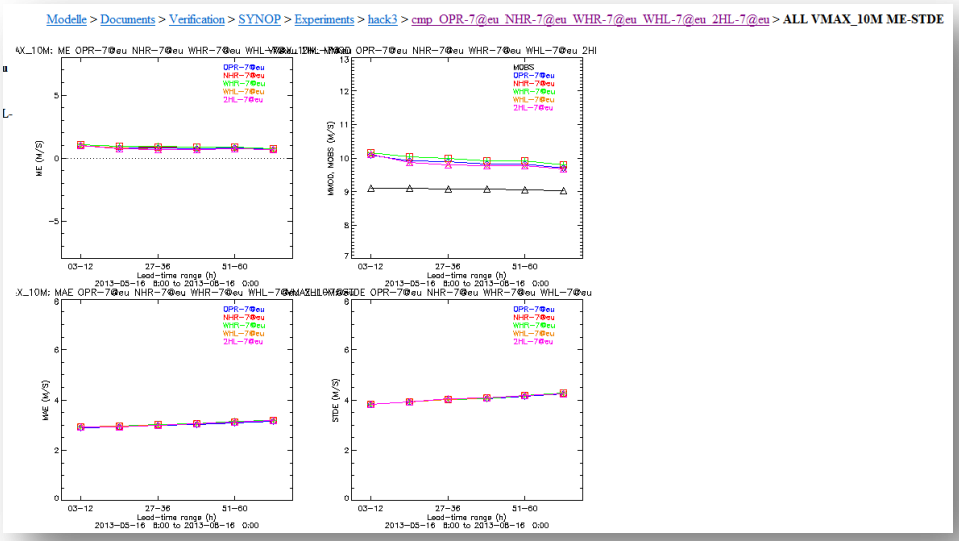
Root mean square error for TOT_PREC12



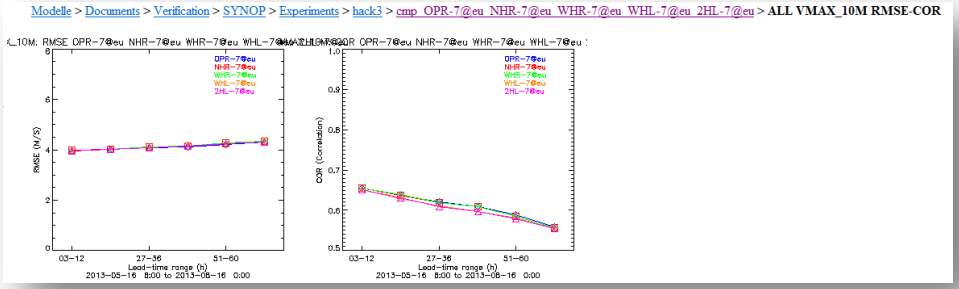
FBI for TOT_PREC12



Mean Error for VMAX_10M

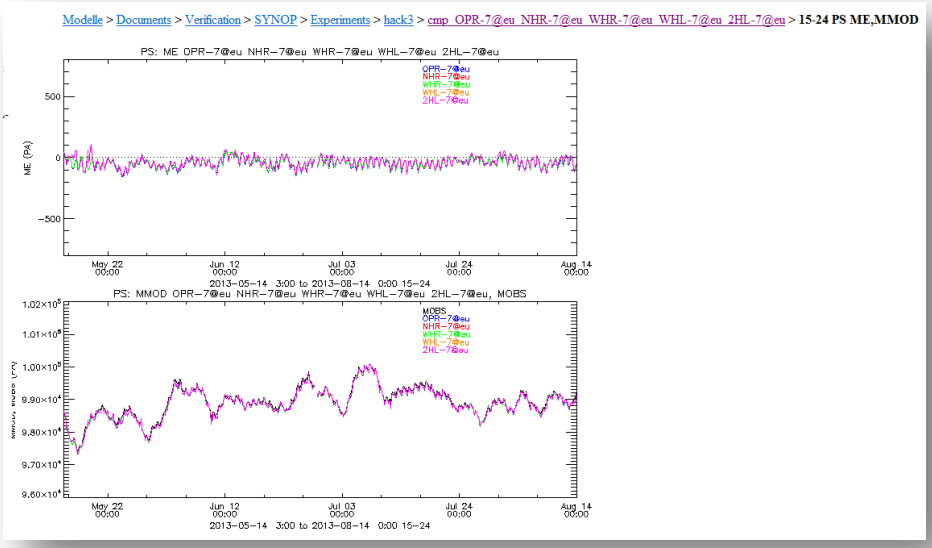


Root mean square error for VMAX_10M

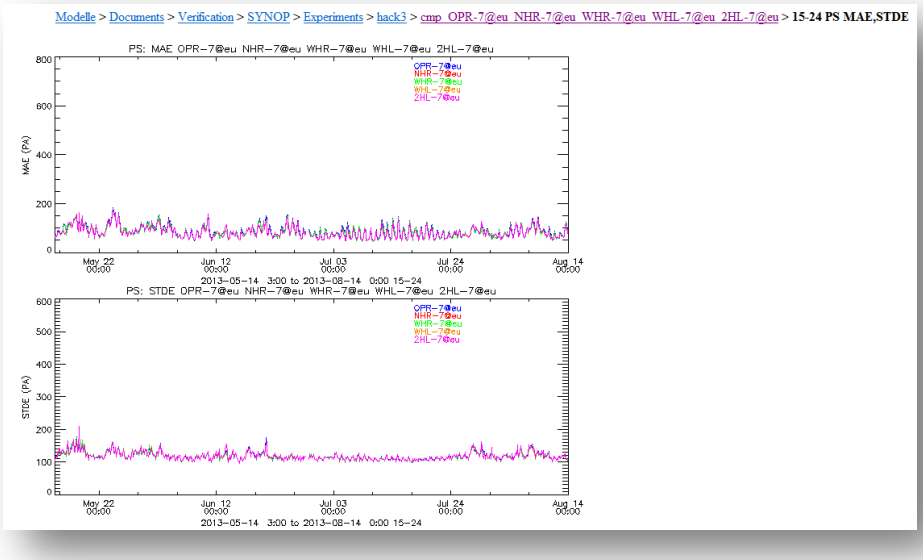


Appendix B: Time series of verification scores

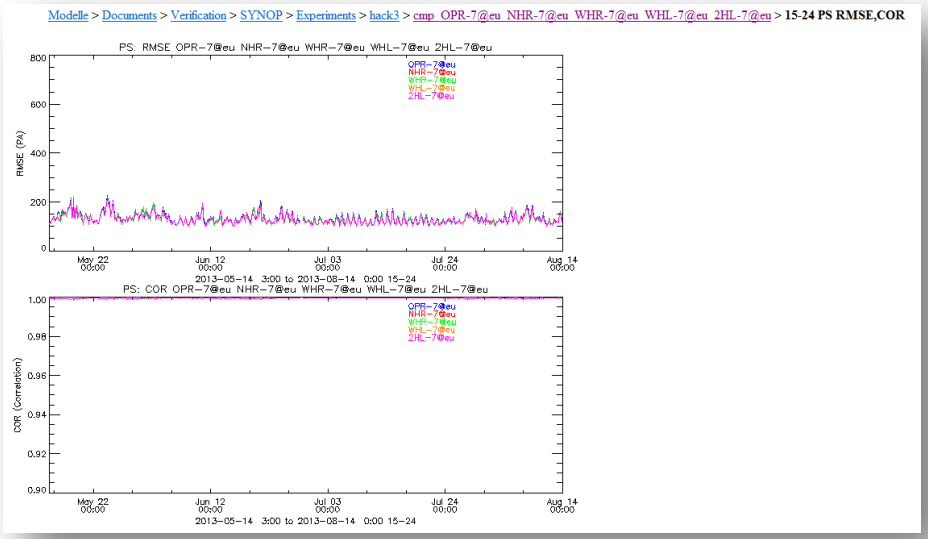
ME and MMOD for PS



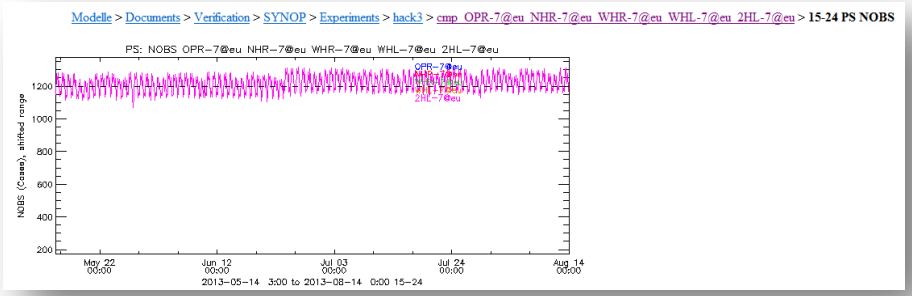
MAE and STDE for PS



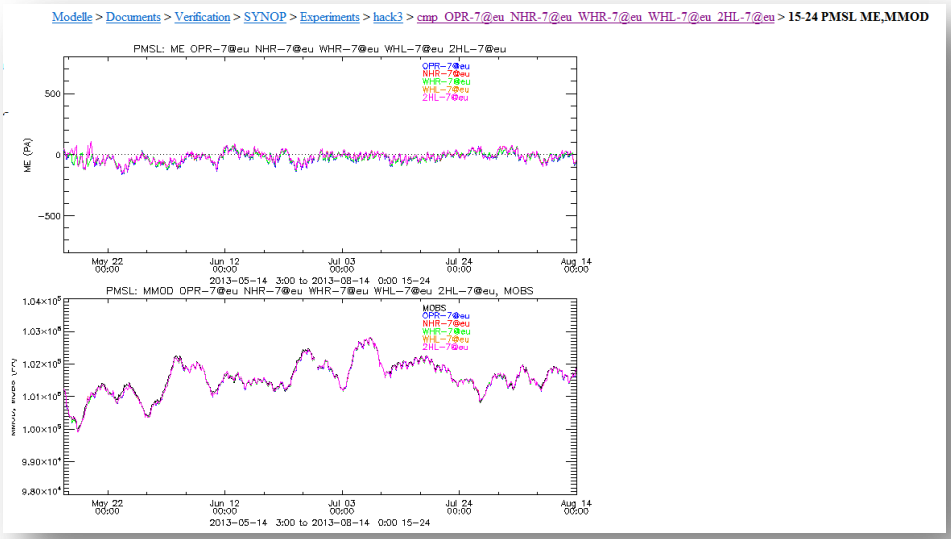
RMSE and COR for PS



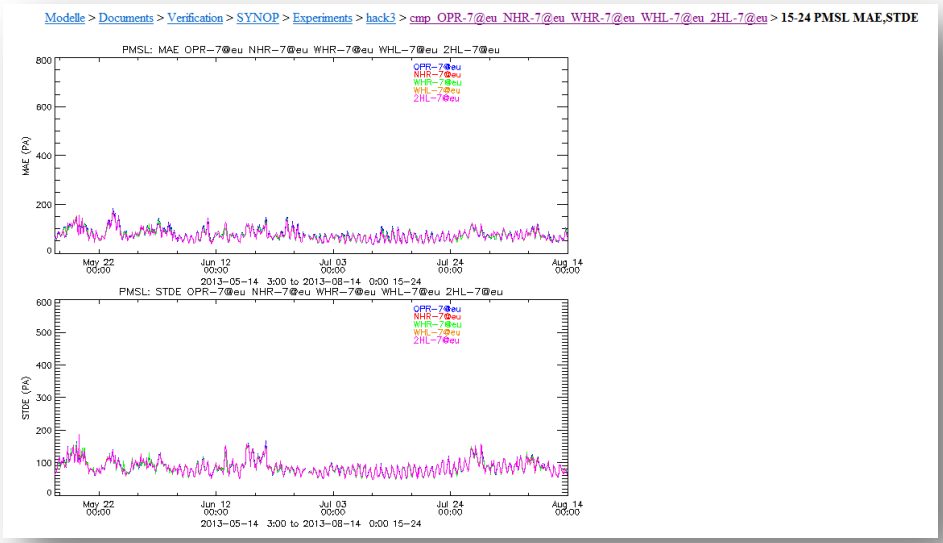
NOBS for PS



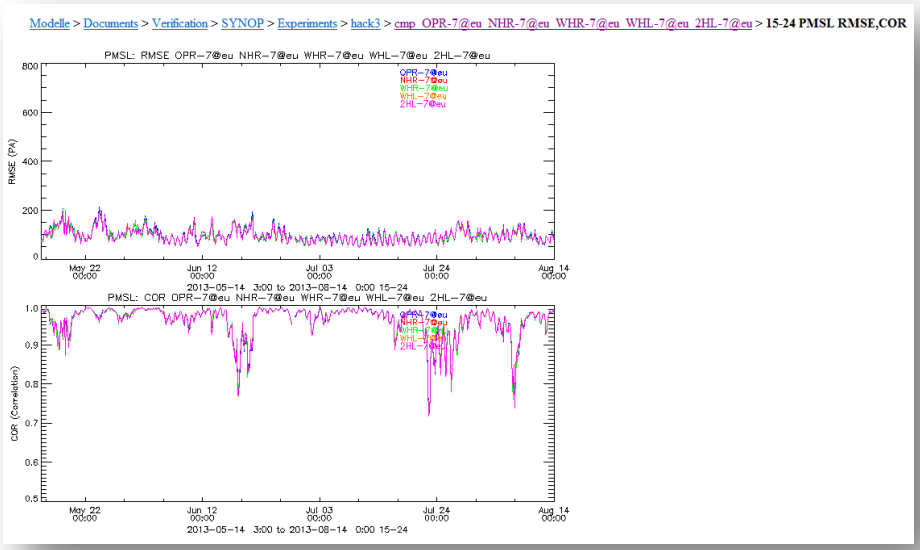
ME and MMOD for PMSL



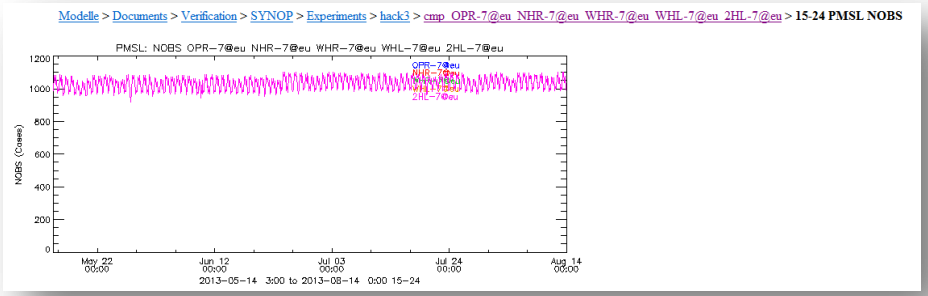
MAE and STDE for PMSL



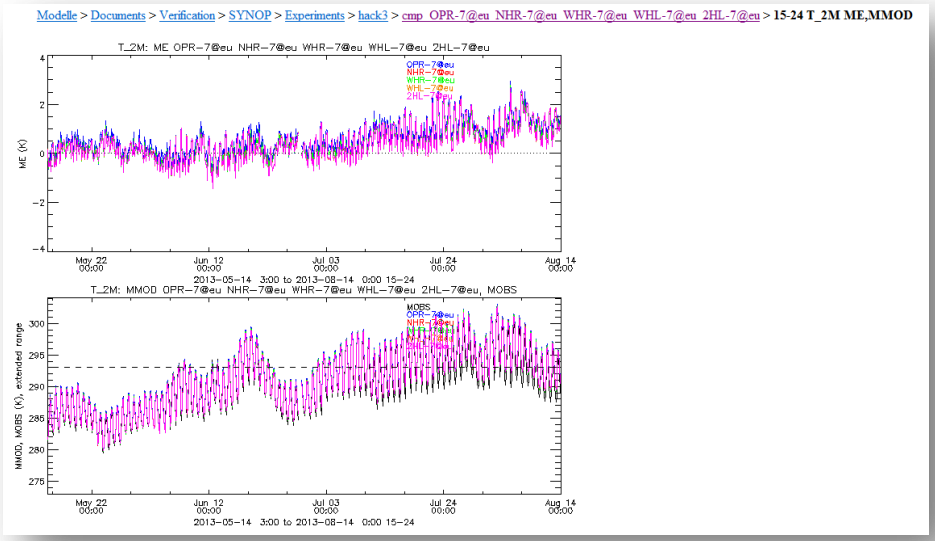
RMSE and COR for PMSL



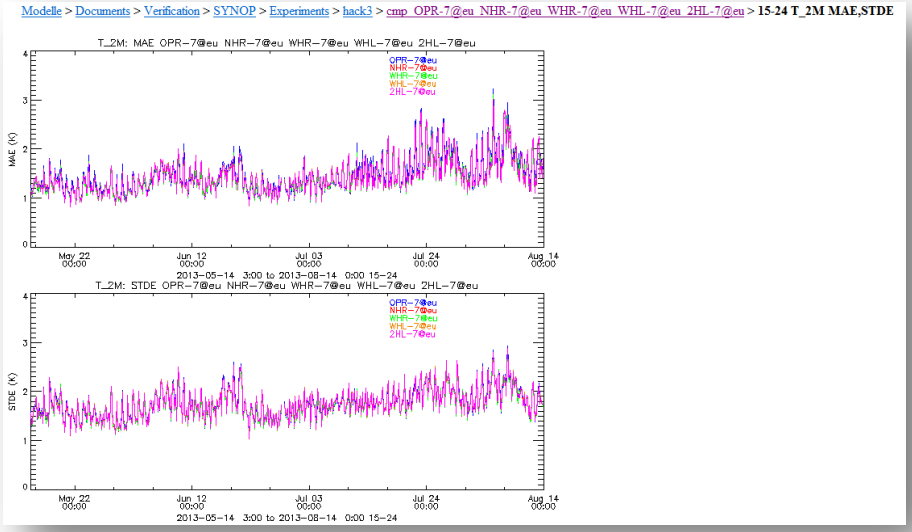
NOBS for PMSL



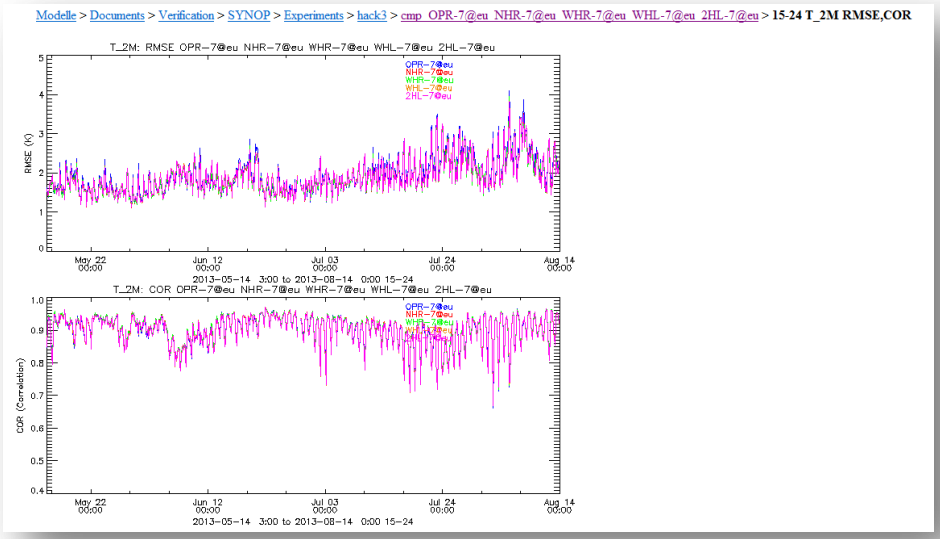
ME and MMOD for T_2M



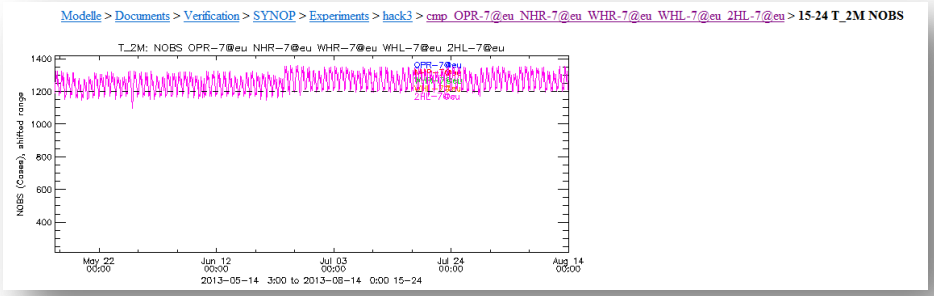
MAE and STDE for T_2M



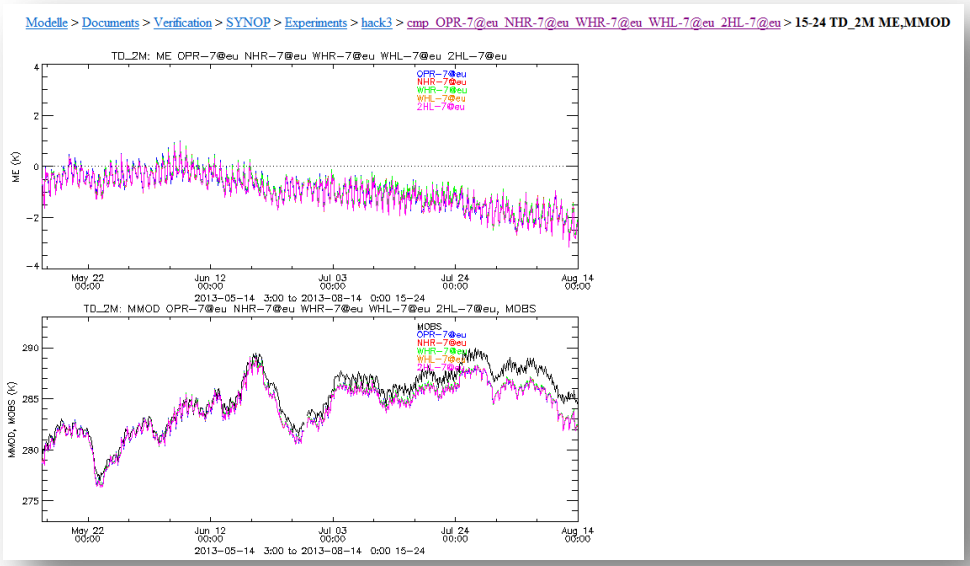
RMSE and COR for T_2M



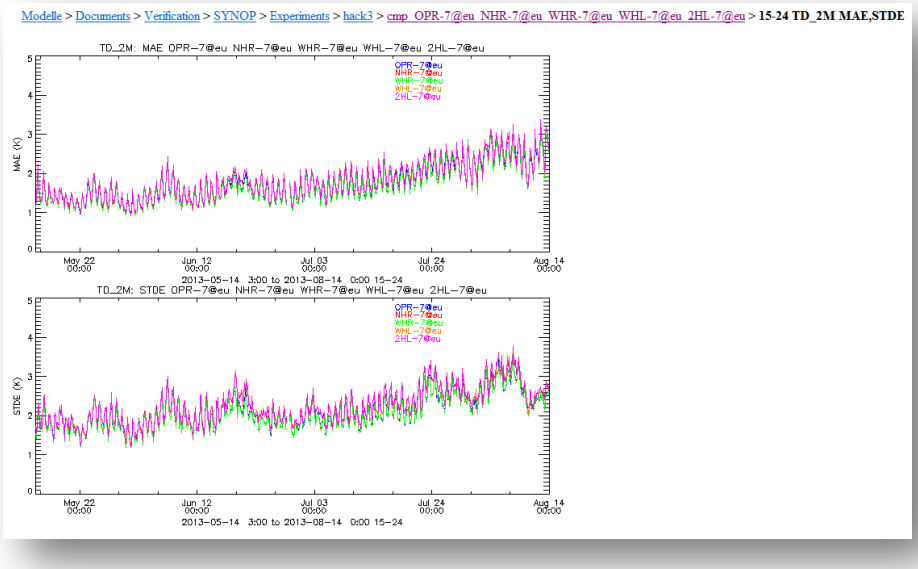
NOBS for T_2M



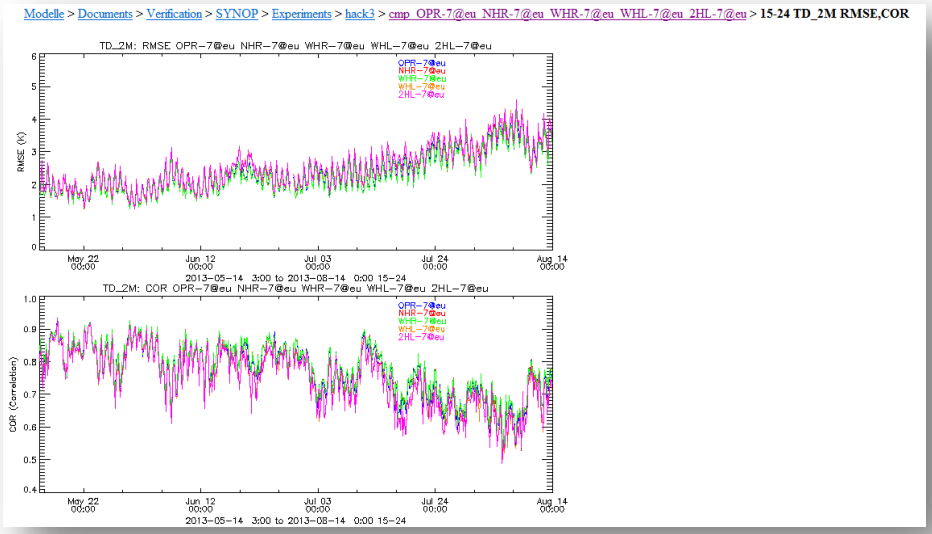
ME and MMOD for TD_2M



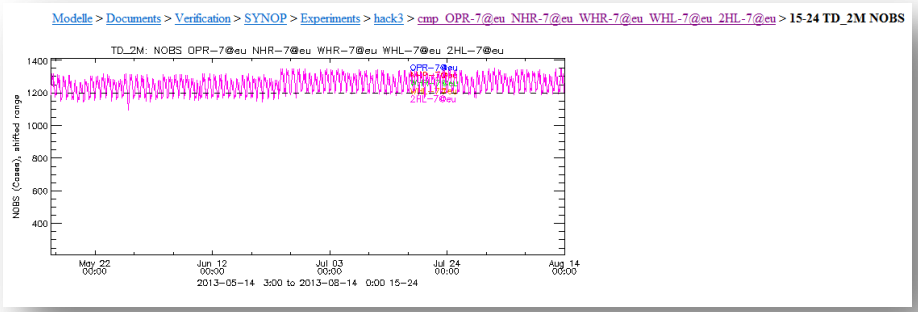
MAE and STDE for TD_2M



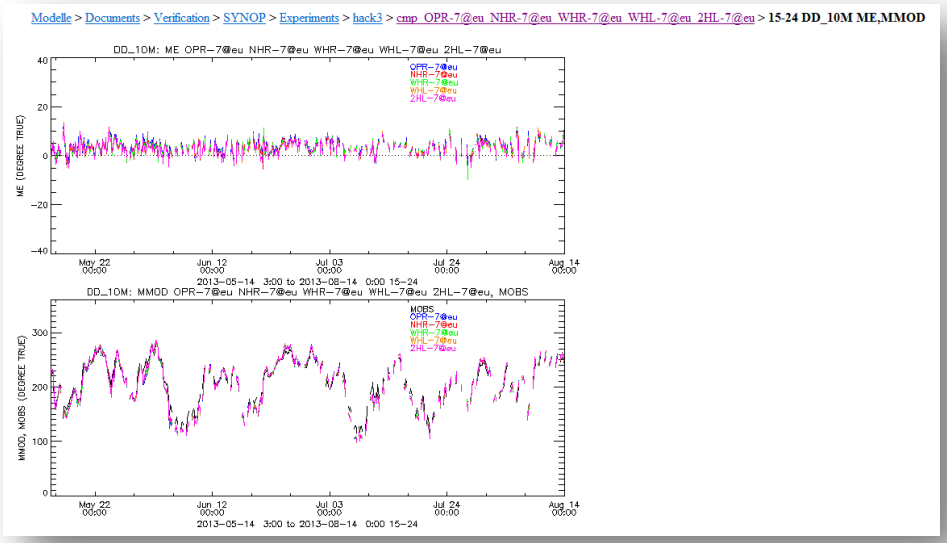
RMSE and COR for TD_2M



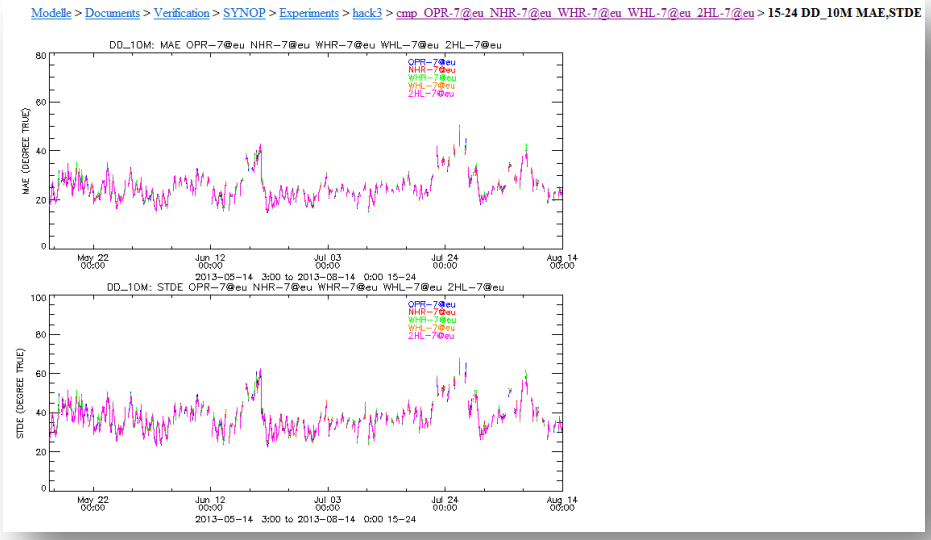
NOBS for TD_2M



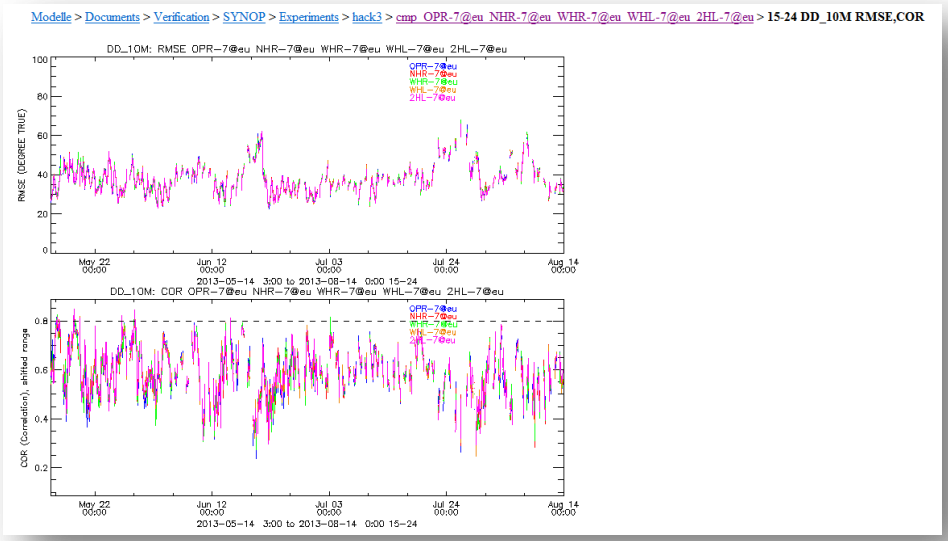
ME and MMOD for DD_10M



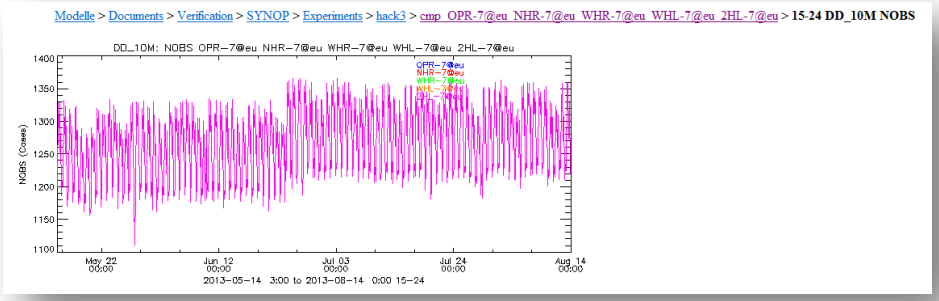
MAE and STDE for DD_10M



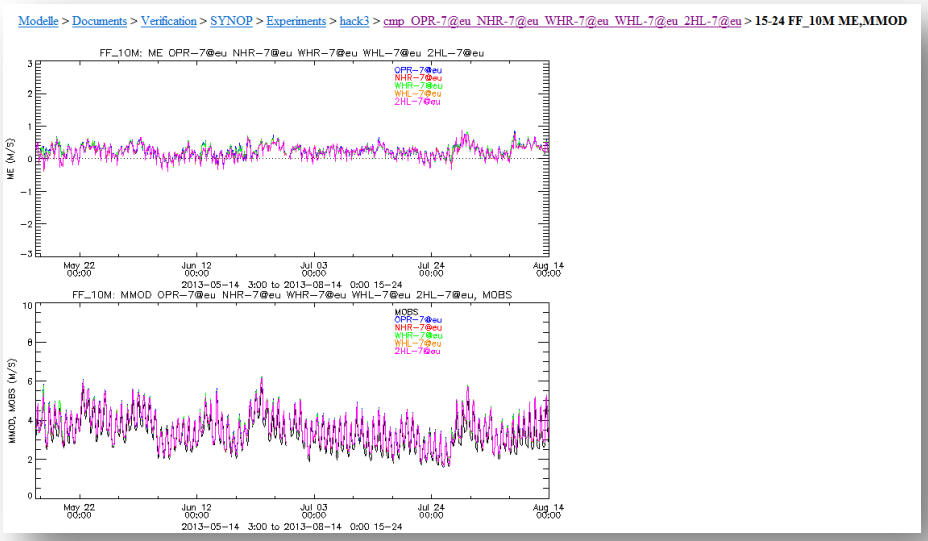
RMSE and COR for DD_10M



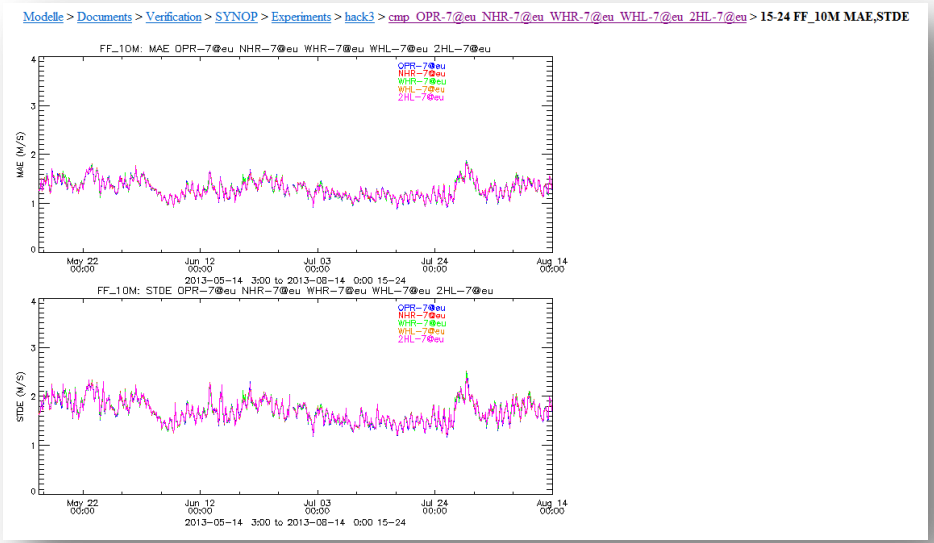
NOBS for DD_10M



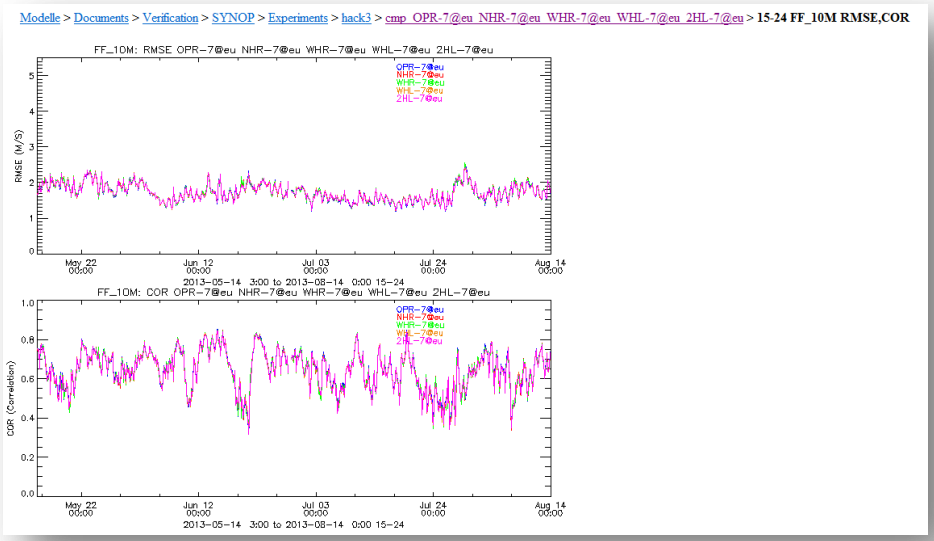
ME and MMOD for FF_10M



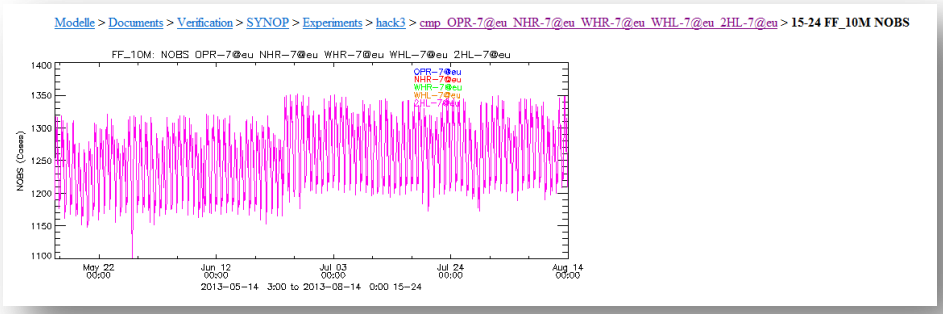
MAE and STDE for FF_10M



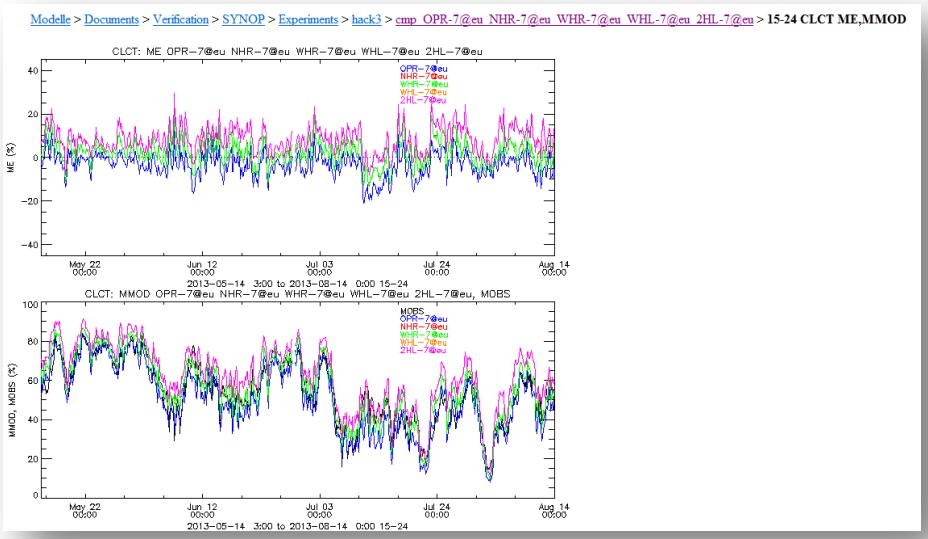
RMSE and COR for FF_10M



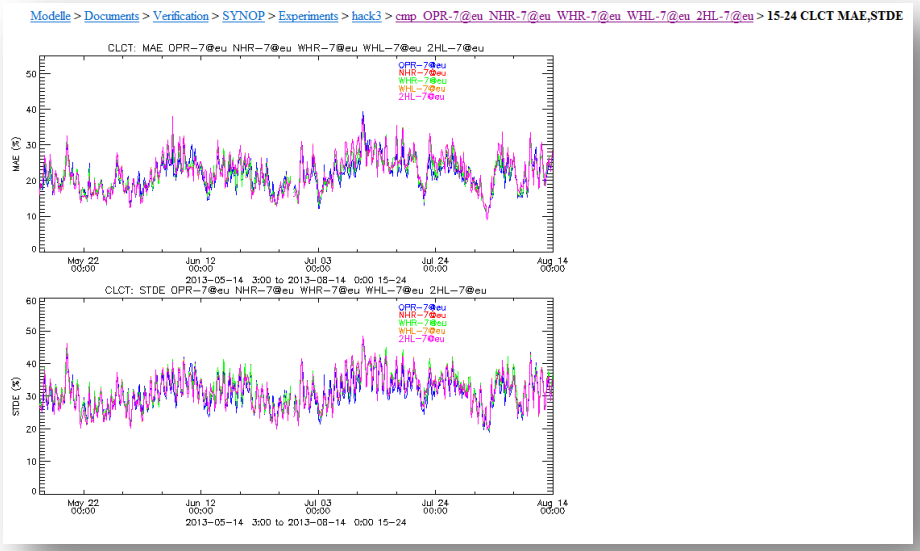
NOBS for FF_10M



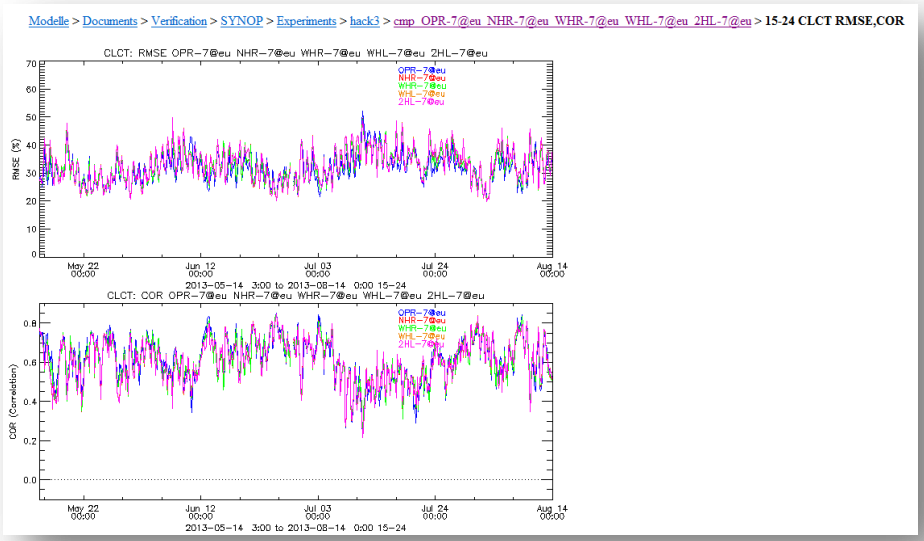
ME and MMOD for CLCT



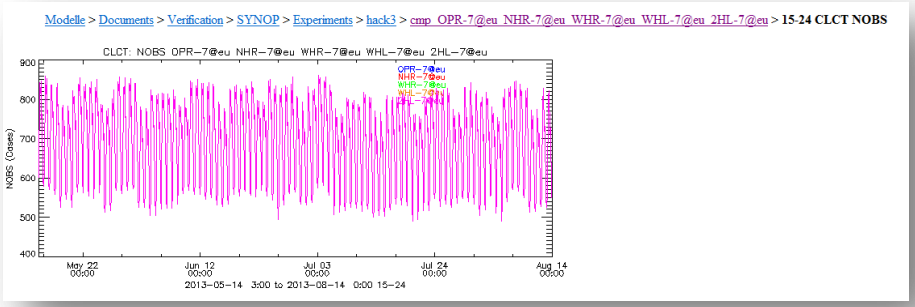
MAE and STDE for CLCT



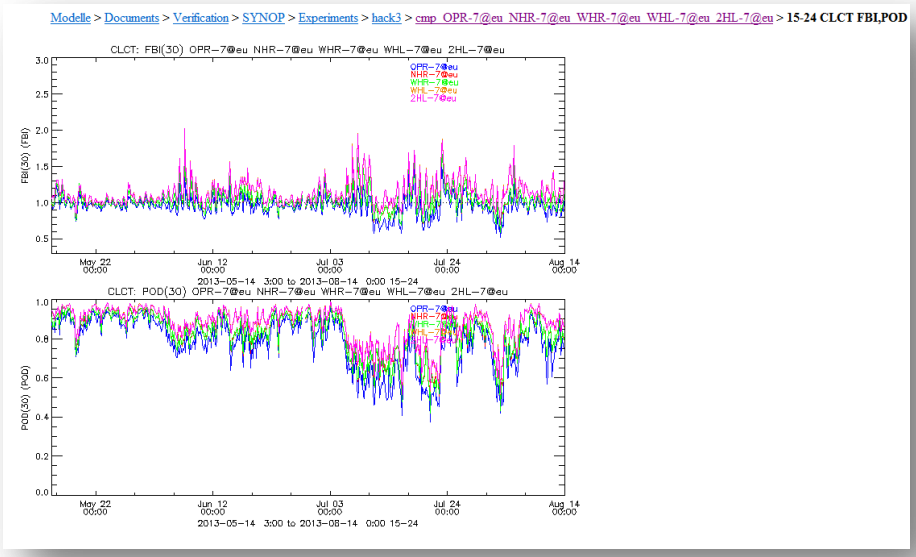
RMSE and COR for CLCT



NOBS for CLCT



FBI and POD for CLCT



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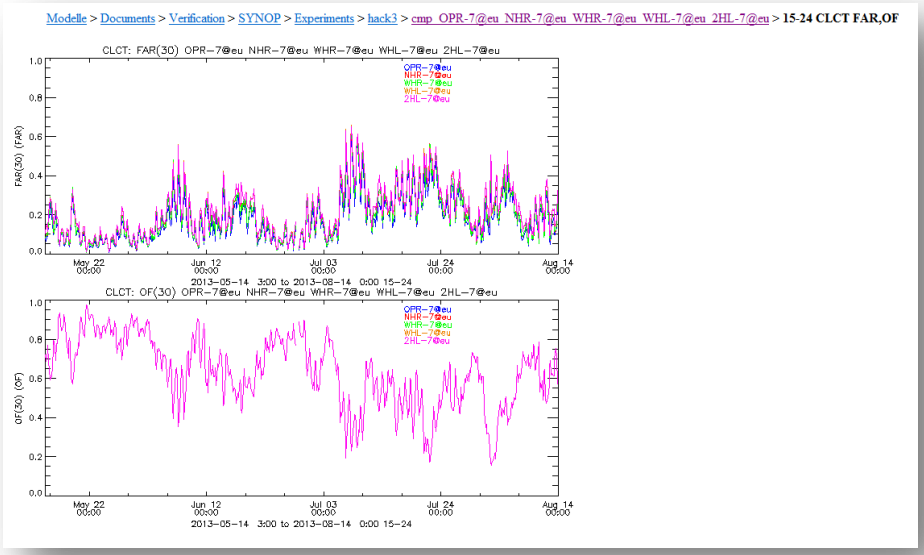
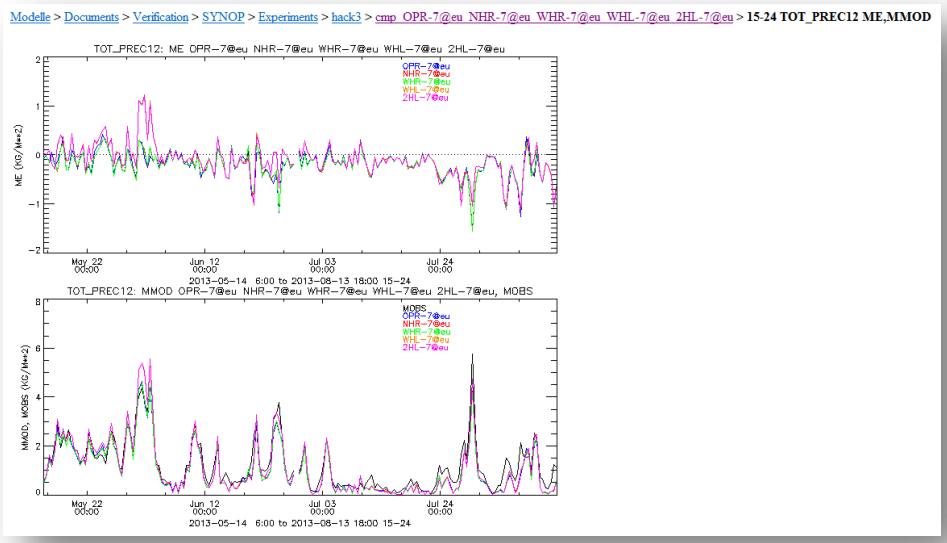


ME and MMOD for TOT_PREC12



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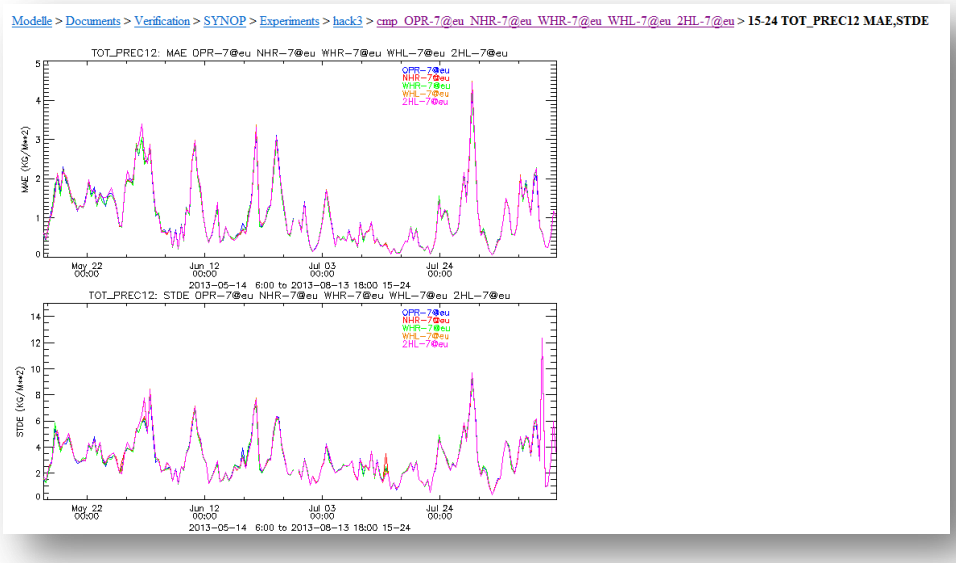

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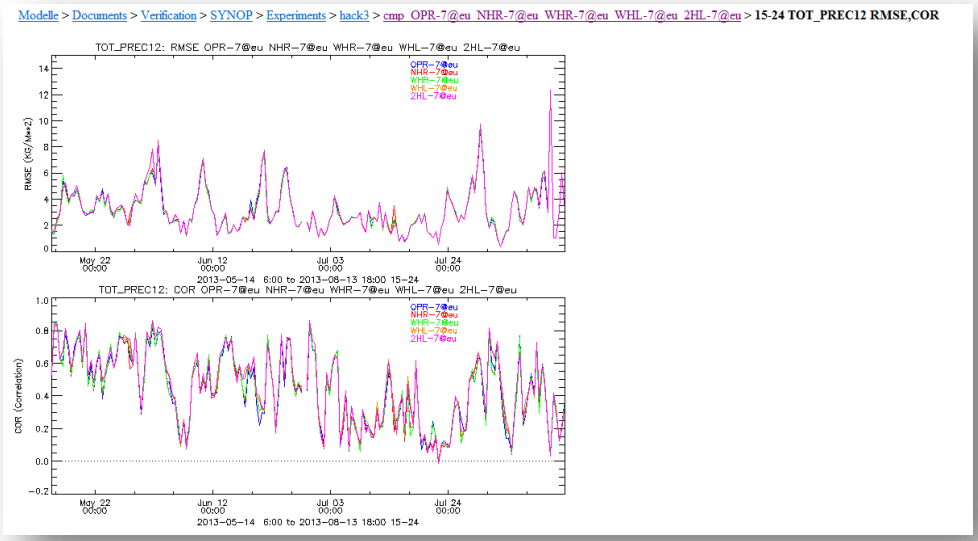

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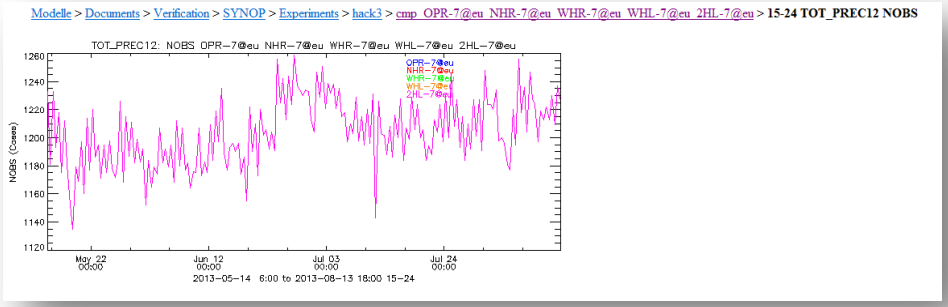

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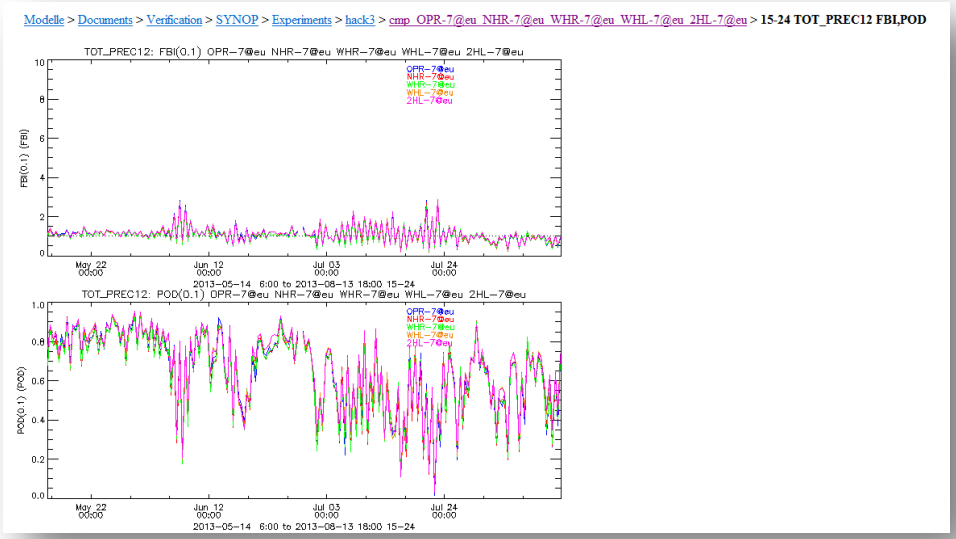

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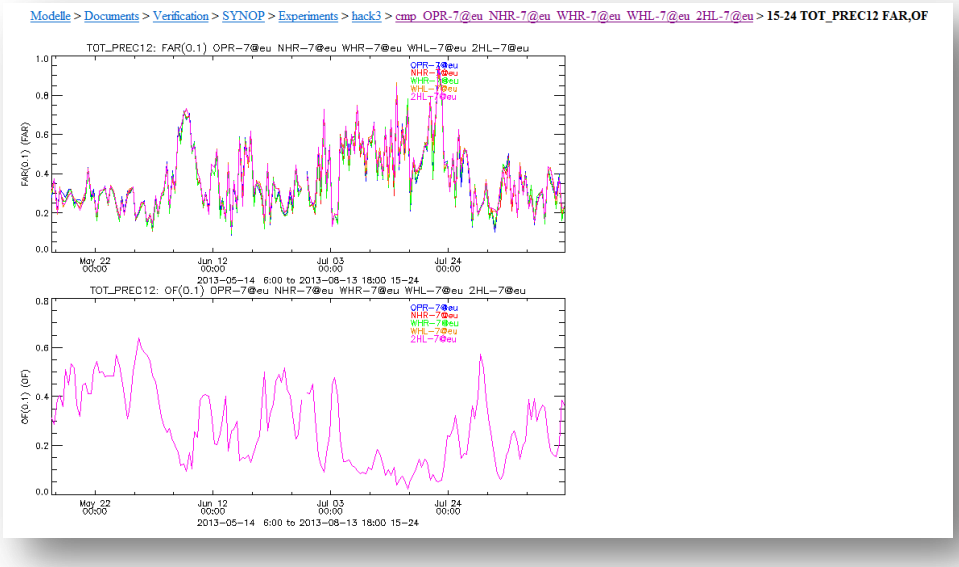
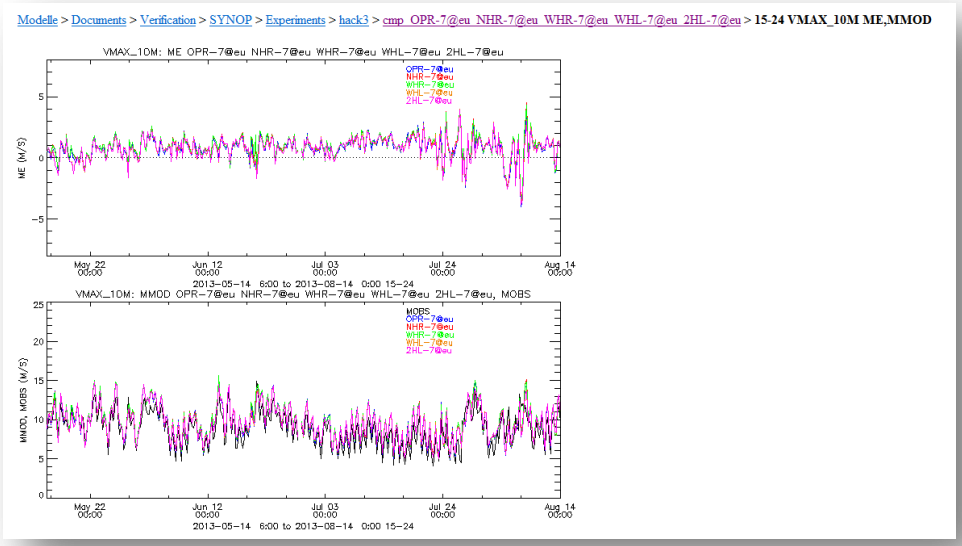
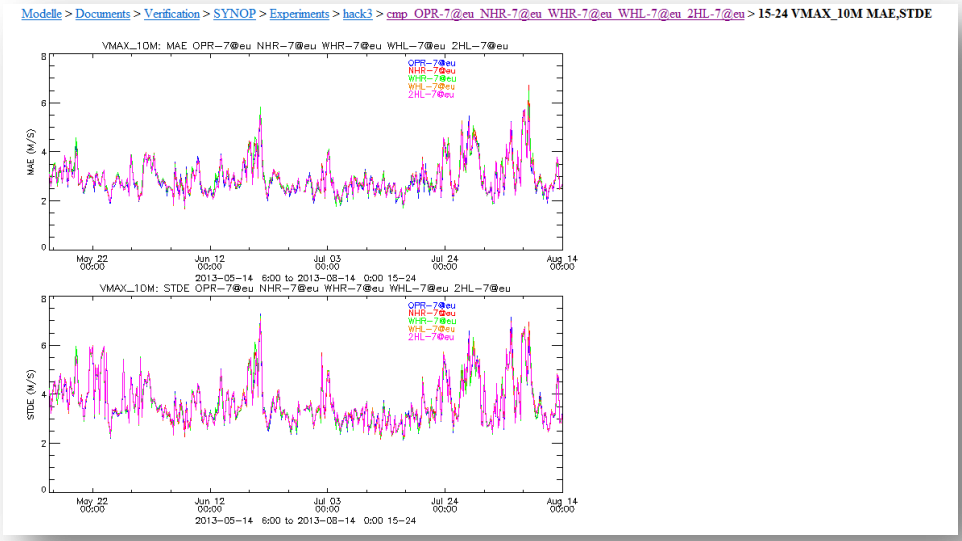


ME and MMOD for VMAX_10M



MAE and STDE for VMAX_10M



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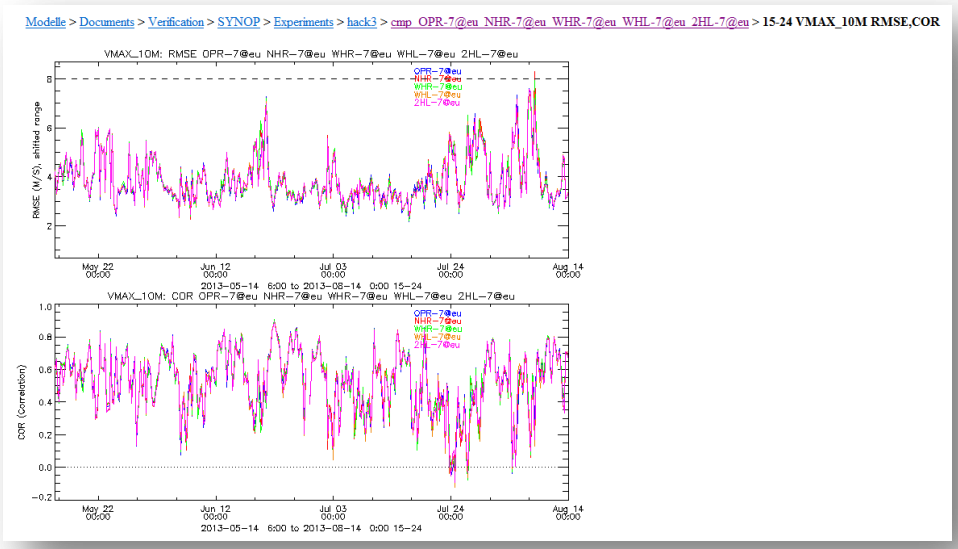

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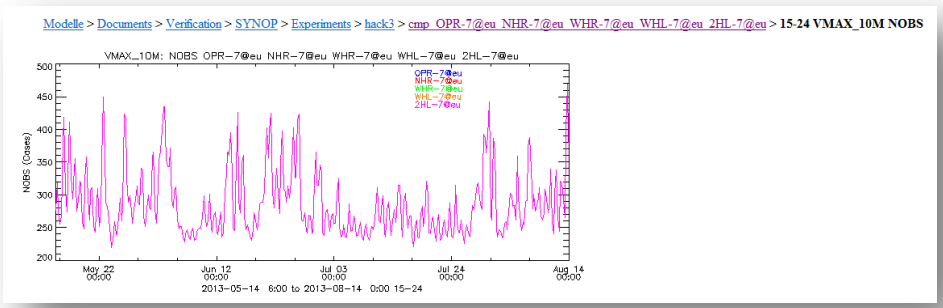
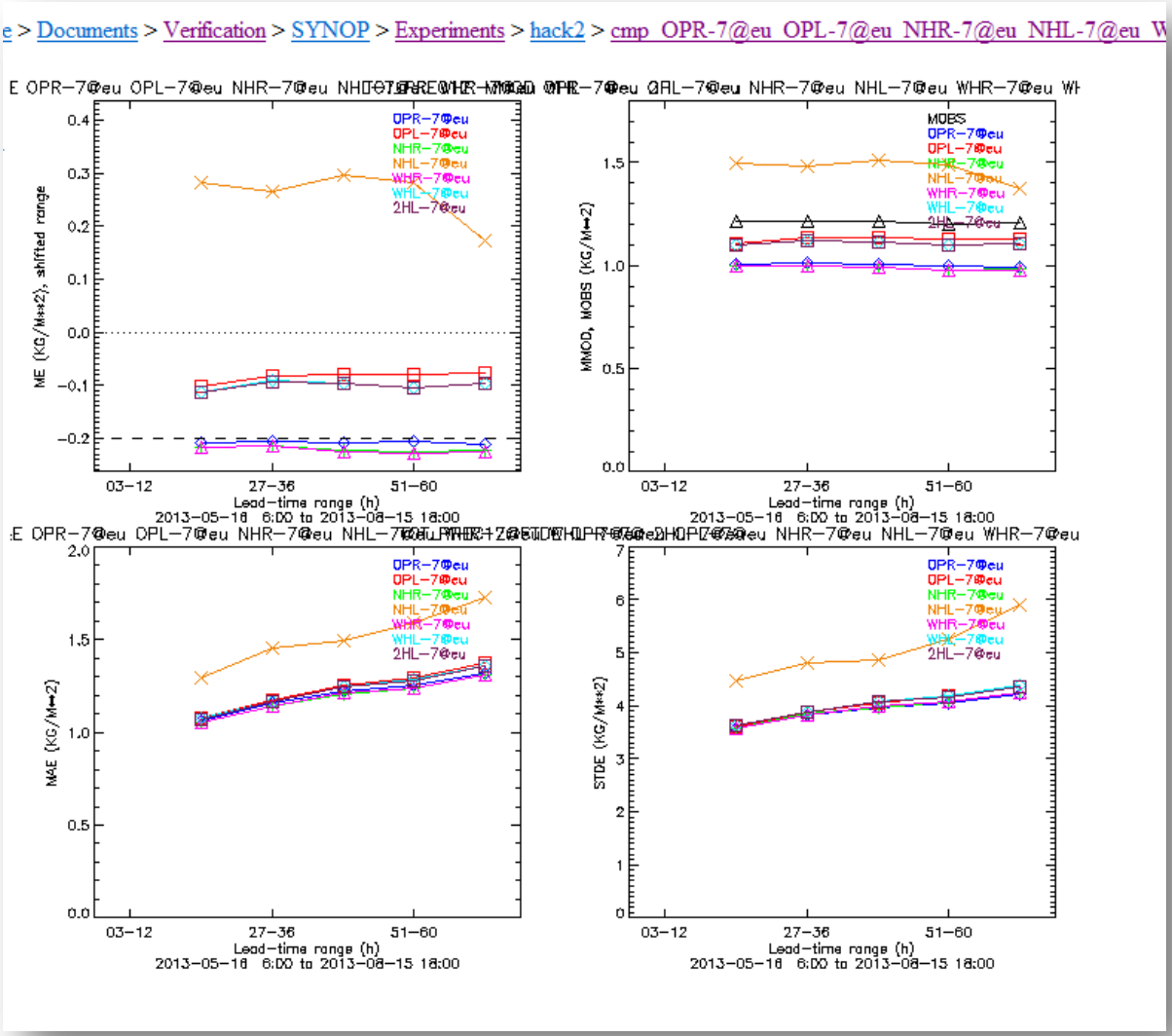


Appendix C: Total scores for TOT_PREC12 including the removal of all inconsistencies in the Leapfrog core



References

Roches A. and Fuhrer O., 2012. Tracer module in the COSMO model. Technical Report No. 20. http://www.cosmo-model.org/content/model/documentation/techReports/docs/techReport20.pdf