The impact of satellite data within the ECMWF system

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Background

- ~ 40 millions observations from 60 instruments are daily assimilated at ECMWF (*see S. English poster Session 6: NWP)*
- The assumed **R** and **B** play an important role in determining the weight of a given observation in the assimilation system.
- The *adjoint-based methods* makes possible forecast sensitivity to data assimilation system input parameters [**y, R,** $\mathbf{x_b}$ **, B**]
    - *Forecast sensitivity to observations (FSO)* – is used to monitor the impact of observations to reduce short-range forecast errors.
    - *The forecast **R**- and **B**-sensitivities* associated to a short-range forecast error measure may be used to provide guidance to error covariance tuning procedures.
- Complementary tools: *OSEs*, *Observation influence in the analysis*

Outline

- Estimating observation errors variances
  - application to IASI/Metop-A observations used in the ECMWF system.

- Analyse the assimilation and forecast system performance through
  - Impact on departure statistics
  - Forecast scores & Total energy error norm
  - Observation influence & FSO

- Conclusions

Ways to estimate observation-errors variances

- Guidance for the specification of observation-errors variances can be obtained from data assimilation system:

  - *Desroziers method*

    An estimate of the observation error variances may be obtained *a posteriori* from the statistical analysis of the observation residuals.

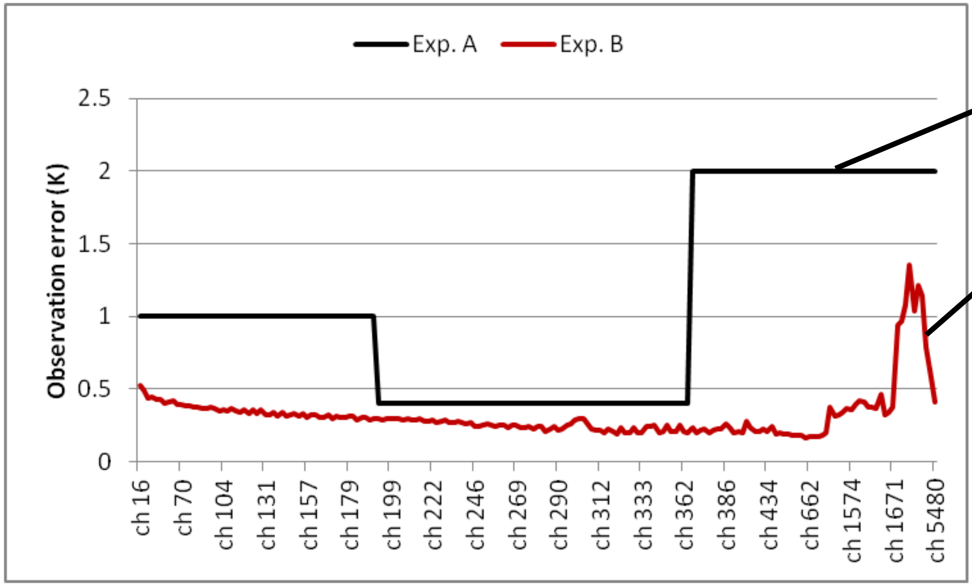
  - *Adjoint-based methods aiming to minimise 24-h forecast error*

  - *Standard deviation of observation-minus-background*
  - *Hollingsworth/Lönnberg method*
  - *…*

Experiment with modified observation error variances (Desroziers method)

- **Exp. A**: Baseline = **Conventional observations** + **IASI /Metop-A** with **R** diagonal as in ECMWF operations
- **Exp. B:** As Exp. A, but with updated diagonal **R** for all IASI channels as derived from Desroziers diagnosis;Period: 8 June – 30 July 2012, 12-h 4D-Var, T511/137 levels, CY38R2
- Evaluating the observation impact through
  - Impact on departure statistics
  - Forecast scores & Total energy error norm
  - Observation influence & FSO

IASI: Desroziers estimates of observation errors



Operational observation errors σ_o

Diagnosed observation errors $\tilde{\sigma}_o$

- Diagnosed observation errors are noticeably lower than the operational observation errors for all IASI channels.
- No guarantee is provided that its implementation will have a beneficial forecast impact.

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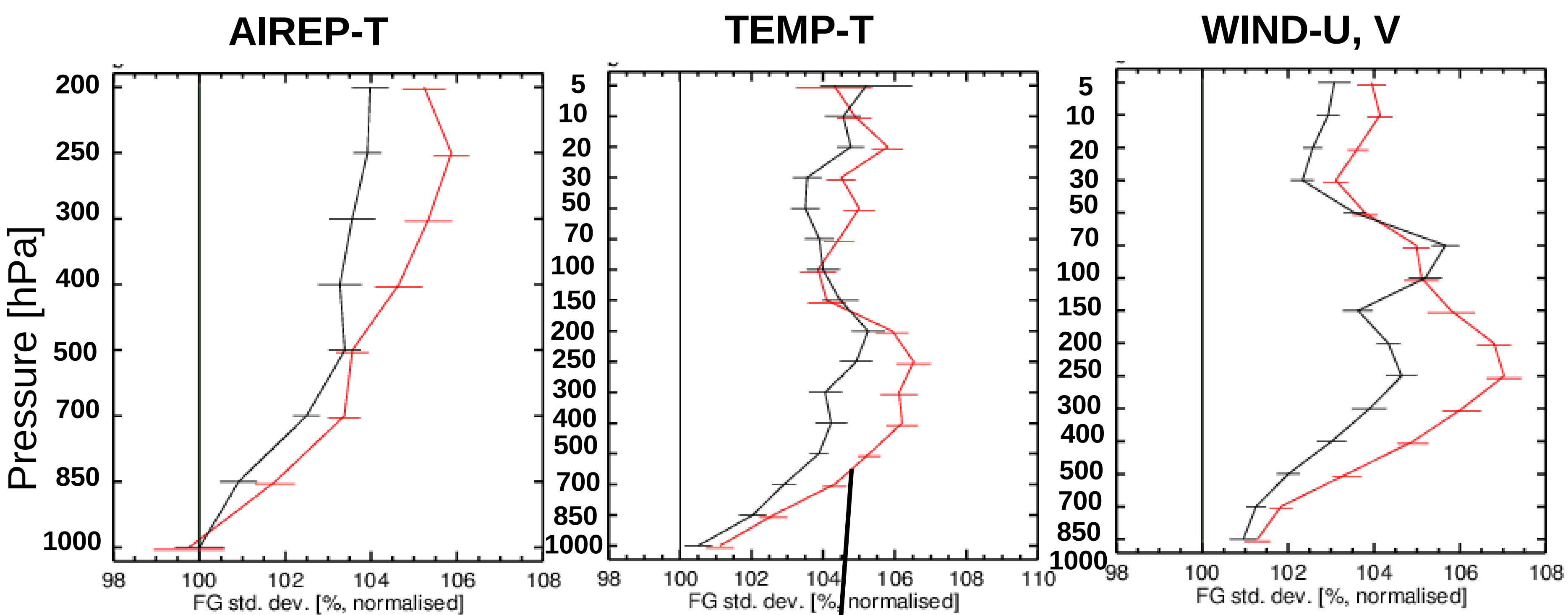
Std. dev. of FG-departure

Normalised by Control, 95% confidence interval

Control: is full observing system, as in ECMWF operations



Exp. A

Exp. B

Exp. B *degrades* T and winds in the FG.

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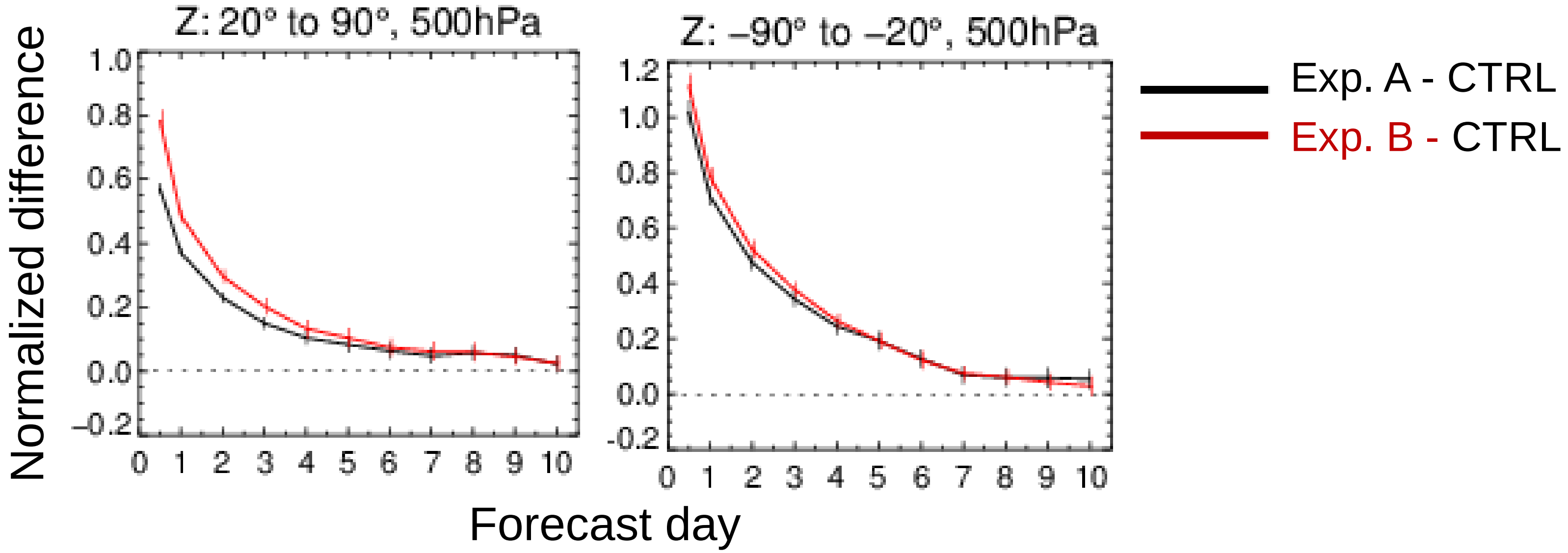
Forecast scores

Normalised change in RMS geopotential forecast error at 500 hPa

Verified against own analysis; 95% confidence error bars

54 days summer 2012.



- Exp.B *degrades* geopotential forecast error scores.

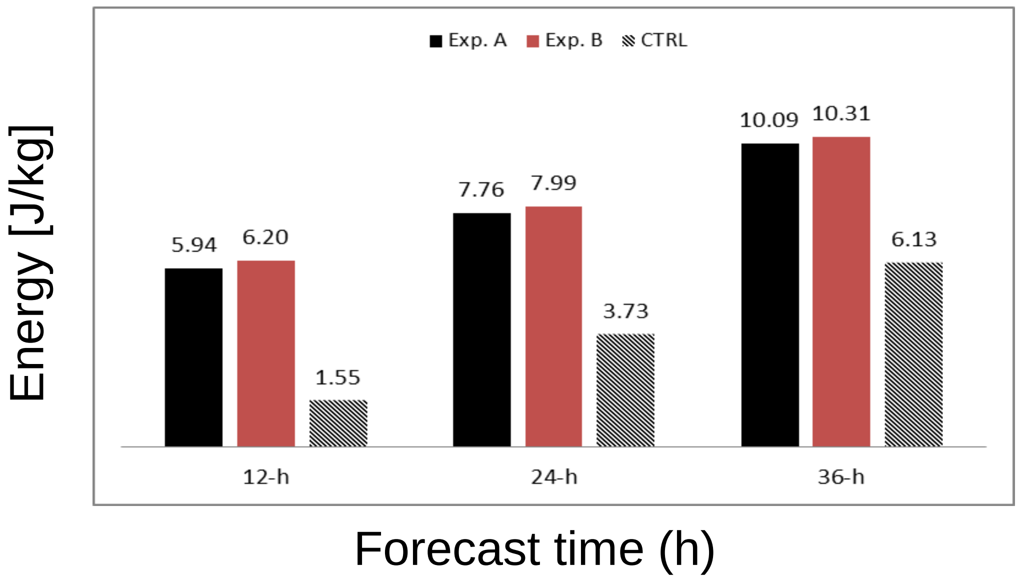
Total energy error norm

- The energy norm evaluates the entire model volume of the atmosphere and calculates a combined error from four meteorological variables.

$$e = \left\| \mathbf{x}_a^f - \mathbf{x}_t \right\|_{\mathbf{E}}^2$$

$$\|\mathbf{x}\|_E^2 = \mathbf{x}^{\mathrm{T}}\mathbf{C}\mathbf{x} = \frac{1}{2}\int_{p_0}^{p_1}\iint_S \left(u^2 + v^2 + \frac{c_p}{T_r}T^2\right)dp\,dS + \frac{1}{2}R_d T_r \int_S (\ln p_{sfc})^2\, dS$$

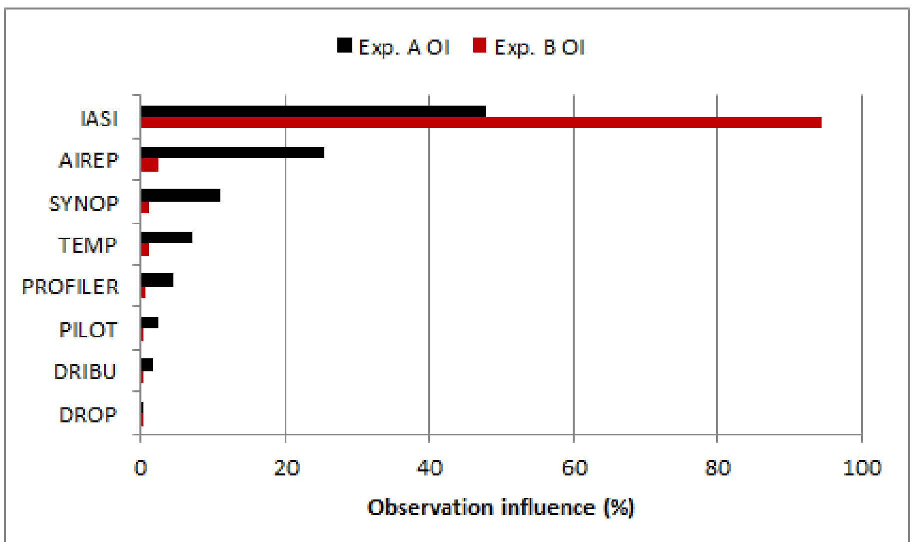
- Higher values denote greater error and values near zero denote an almost perfect forecast (Exp.B has the greatest error).

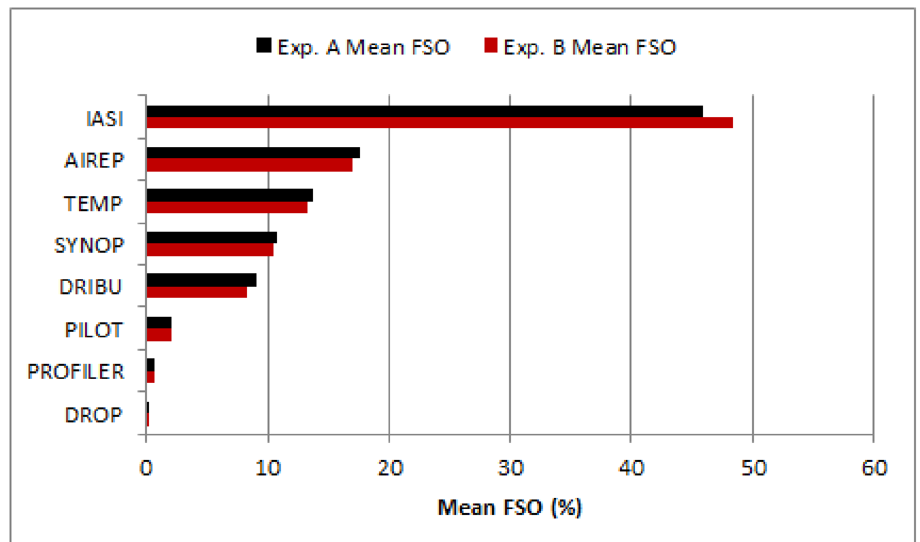


Observation influence (OI) and FSO

- OI and FSO allow to monitor and evaluate the performance of the assimilation system
  - Exp. A: on average the *global observation influence* (9.3%) is low compared to the *influence of the background* (90.7%)
    IASI is providing 47.8% of the OI; conventional data (52.2%)
  - Exp. B: OI is high compared to background influence
    IASI is providing 94.5% of the OI; conventional data (5.5%)

- Poor observation influence → suboptimal observation and/or background weights
- FSO depends on the OI





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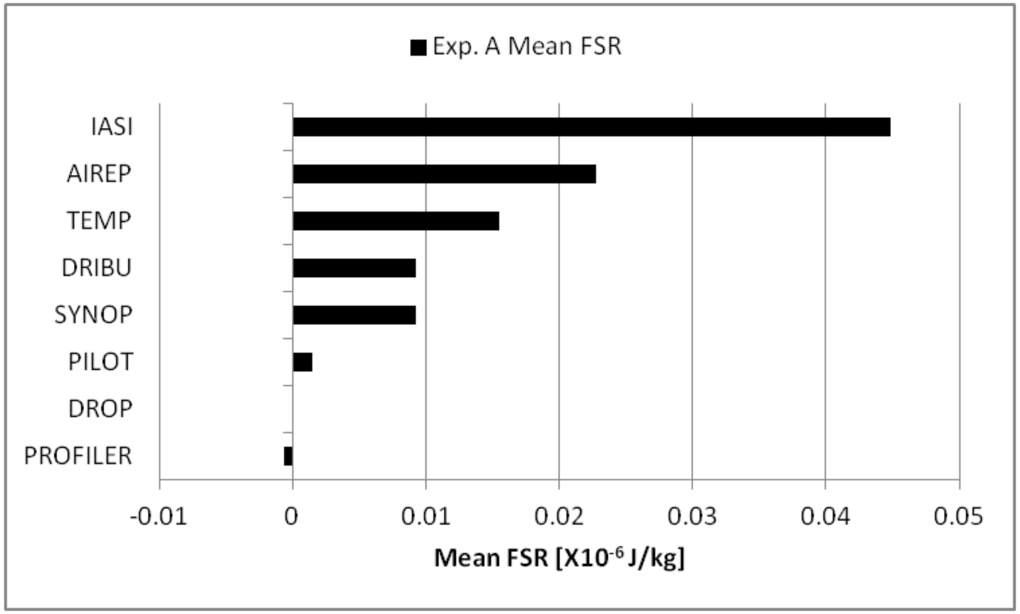
Adjoint-based forecast R-sensitivity



***Positive** sensitivities: identify those observation types whose error variance deflation (**decreasing the** σ_o)* is of potential benefit to the 24-h forecast;

***Negative** sensitivities: identify those observation types whose error variance inflation (**increasing** the σ_o)* is of potential benefit to the 24-h forecast;

- The sensitivity guidance is that the information provided by IASI, AIREP, TEMP, DRIBU, PILOT is under-weighted in the system , so deflation of the assigned observation error variances for those observations is of potential benefit to the forecast.
- The analysis of each observed parameter/ instrument channel is needed to optimize the sensitivity guidance.

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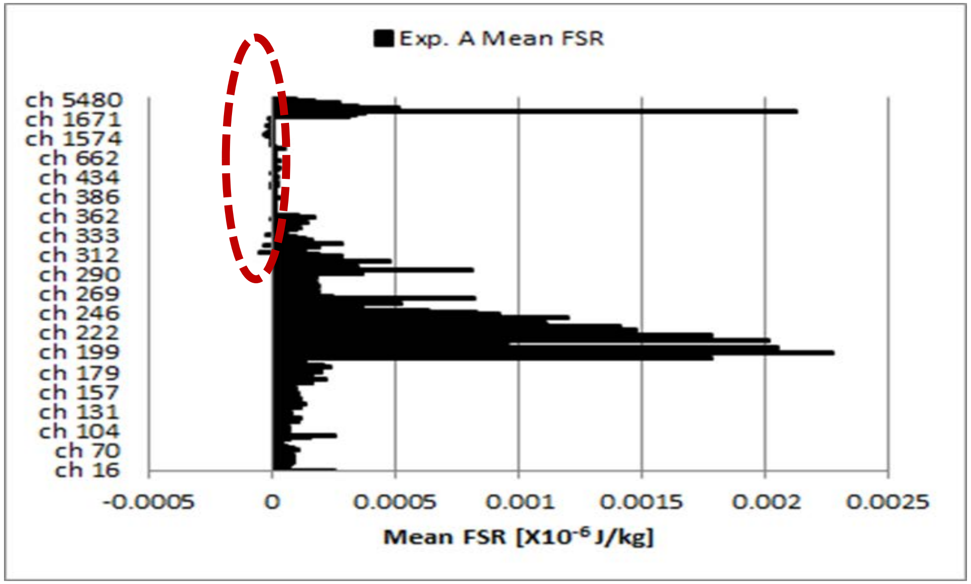
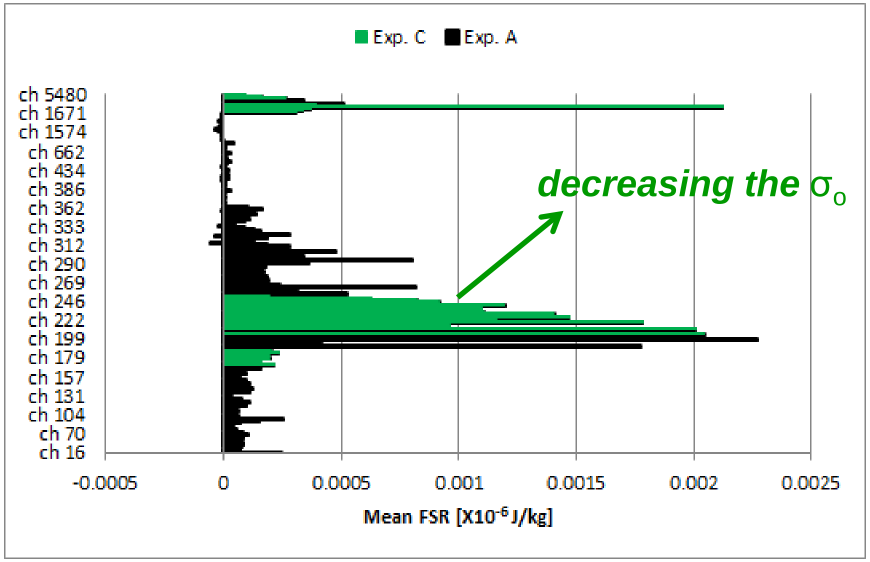
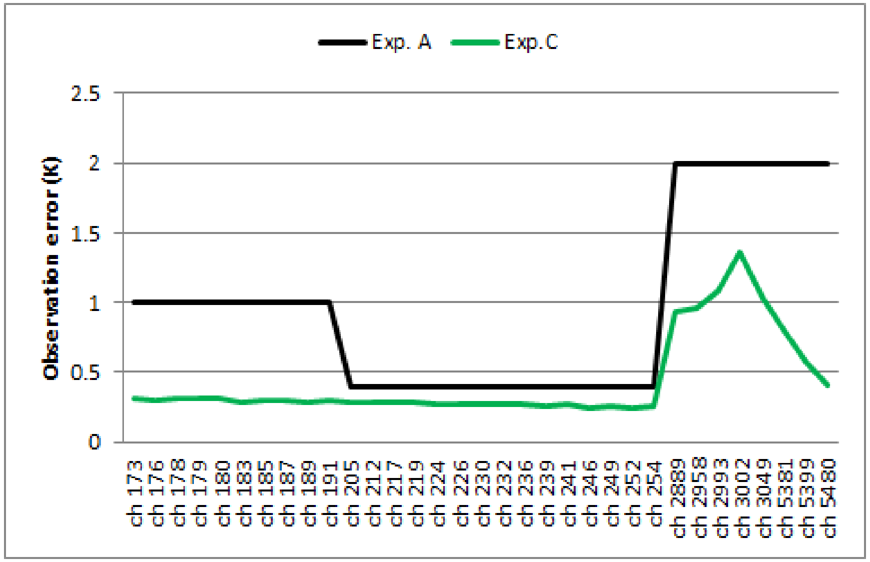
IASI: sensitivity guidance



- Most of the IASI channels display *positive* values of increased magnitude
- Channels in the range 1513-1671 display *negative* sensitivities
  - Inflation of the assigned observation error σ_o is of potential benefit to the forecast
  - An observation error σ_o specification according with Desroziers estimates may have a detrimental impact.

Experiment with modified observation error variances (adjoint-based guidance)



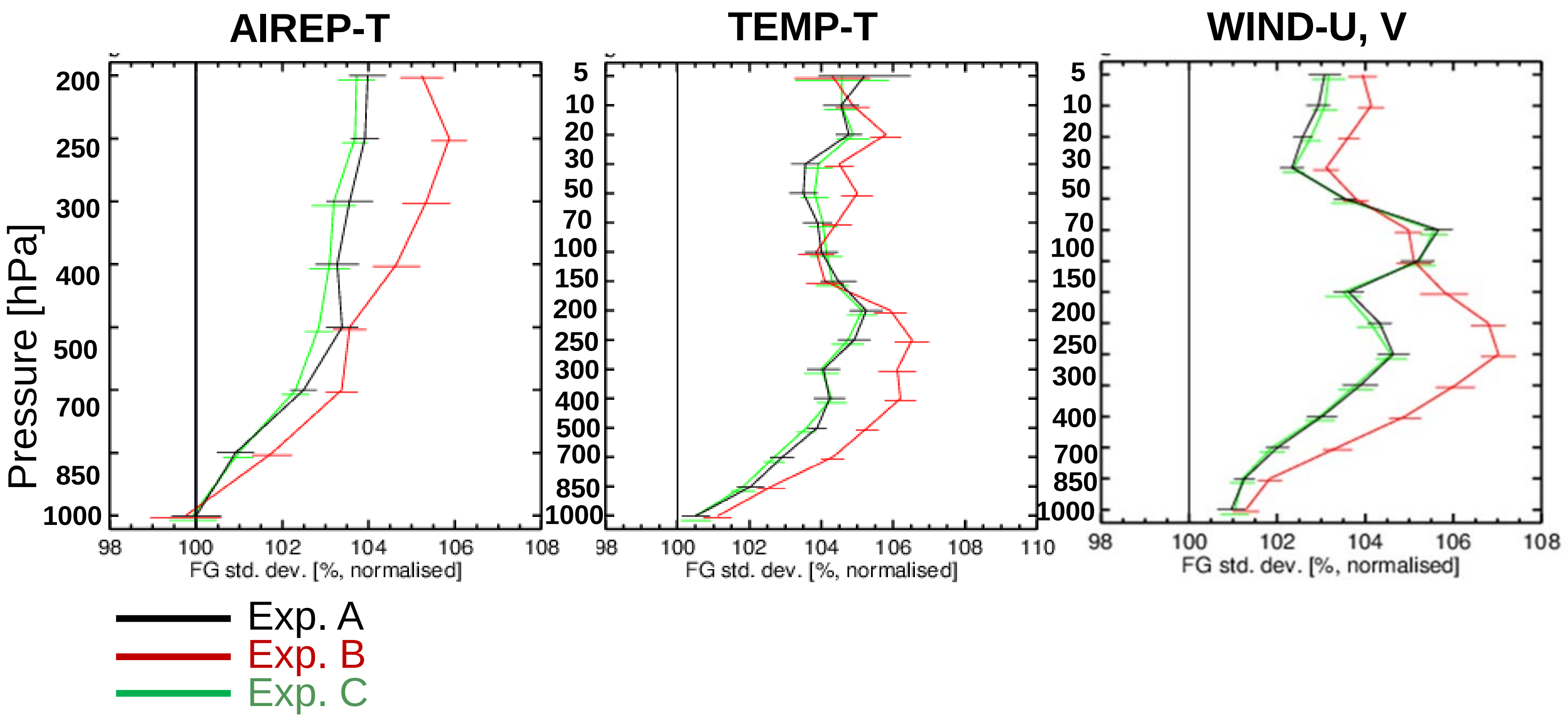


- **Exp. C:** As Exp. A but deflation of the assigned observation error variances for *selected* 33 IASI channels
  - Long-wave CO_2 temperature-sounding channels 173-254 and WV channels 2889-5480.

Std. dev. of FG-departure

Normalised by Control, 95% confidence interval

Control: is full observing system, as in ECMWF operations



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Forecast scores

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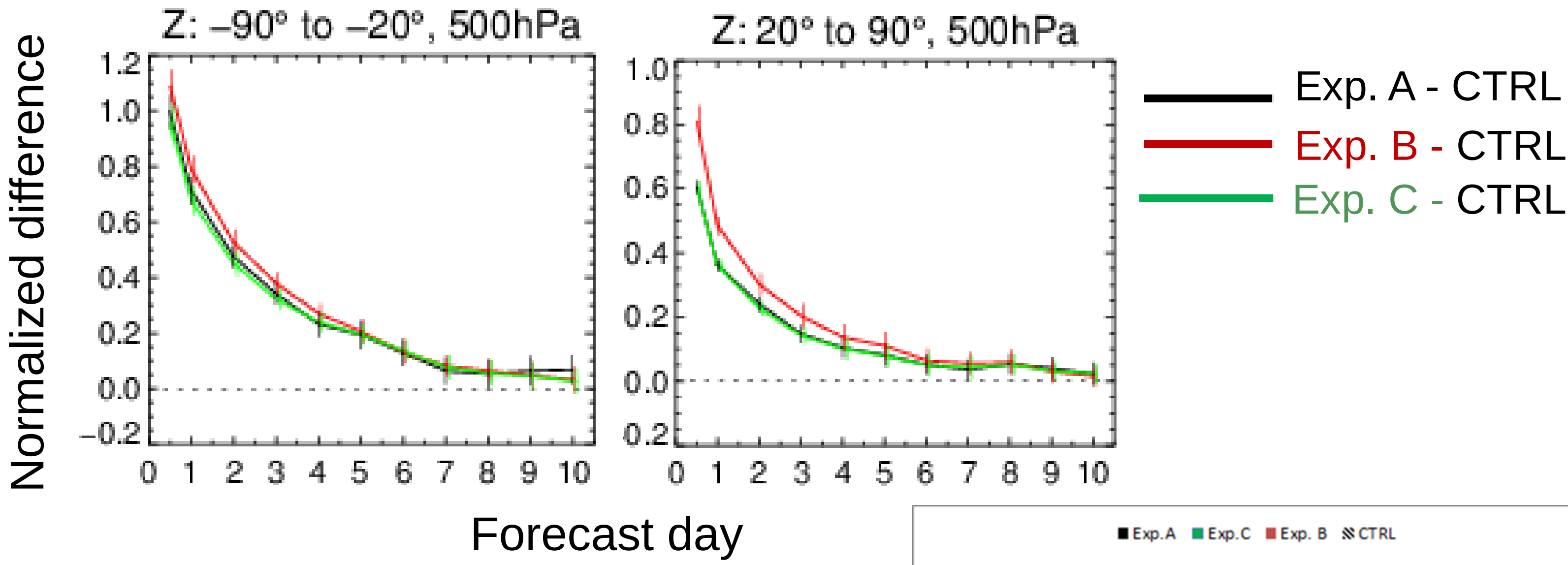
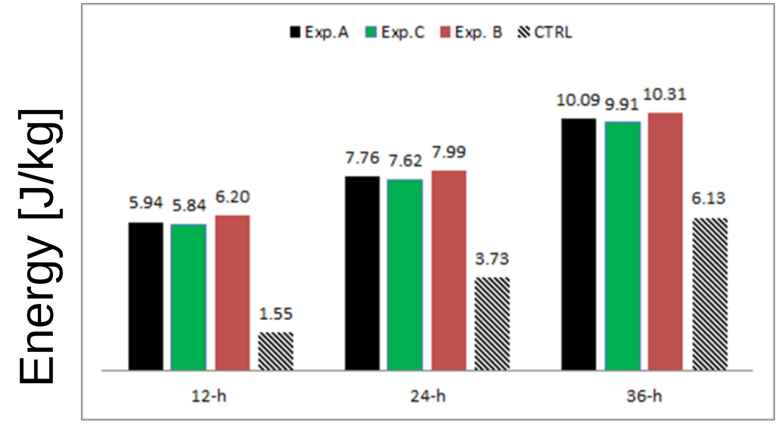
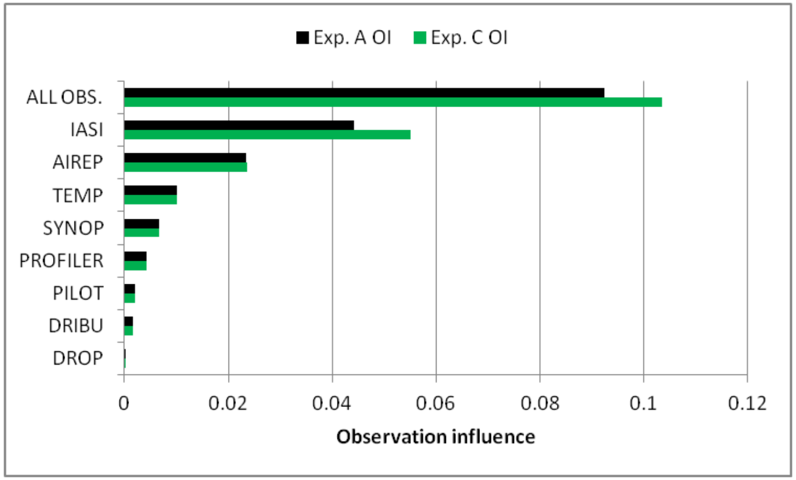


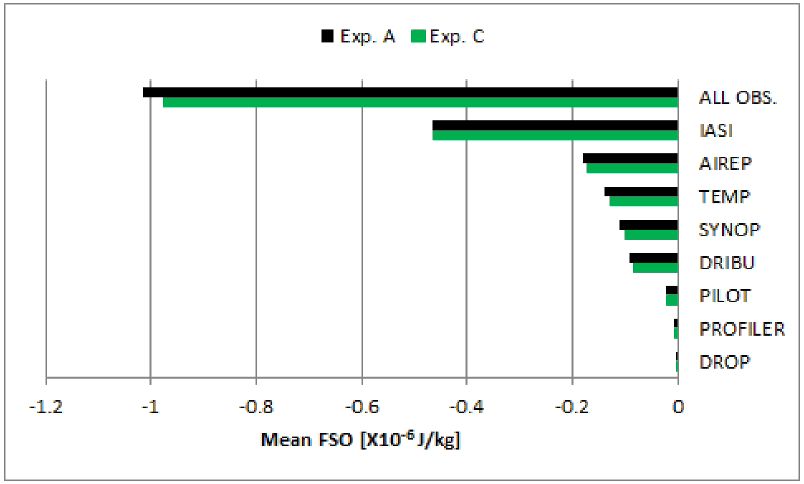
Total energy error norm



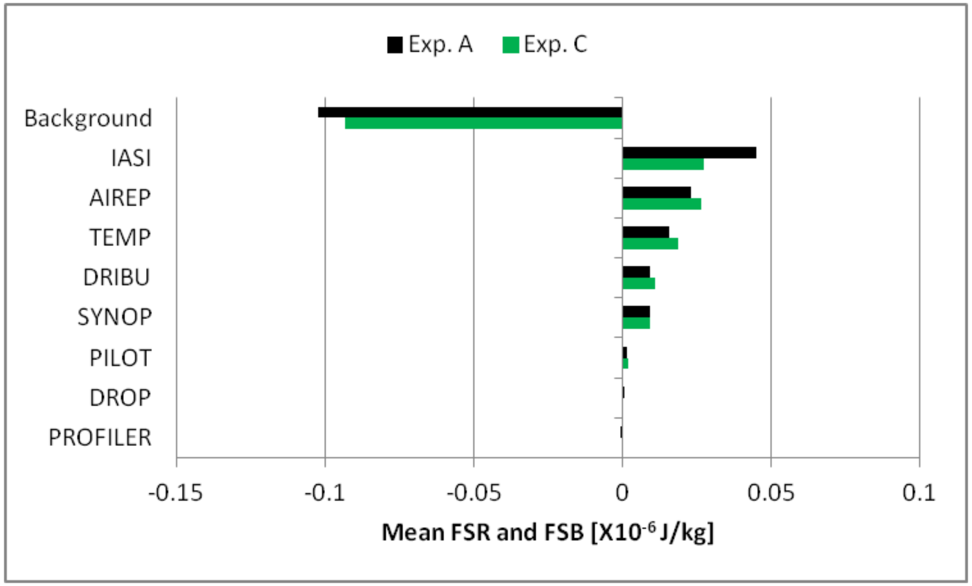
Observation influence and FSO



Analysis sensitivity	Exp. A	Exp. C
Global Observation influence	9.3%	10.3%
Background influence	90.7%	89.7%



Sensitivity guidance: R- and B-sensitivity



*The **B**-sensitivity: guidance on weighting in the assimilation system between the background state and the whole observing system*

*For an optimal system the expected value of the sensitivity to any of the entries in the **B**- and **R**-sensitivities is zero.*

Sensitivity guidance applied to Exp. C:

- Positive **R**-sensitivities for all observation types : decreasing σ_o for all obs.
- Negative **B**-sensitivity: background error covariance inflation.
- An optimal weighting between **B** and **R** information may be explained through a single covariance weight coefficient.

Conclusions

- Results of a study aimed at tuning observation errors variances for IASI/Metop-A based on two methods: *a posteriori diagnosis* and *adjoint-based R-sensitivity*

- Forecast **R**-sensitivity: a proof-of-concept was presented; practical application is not trivial!
  - *identify those instrument channels whose reduced (increased) observation-error values will have a beneficial forecast impact.*
  - *the sensitivity analysis does not provide an optimal value of how much the observation-error variances should be changed.*
  - *validation through OSEs is needed to assess the data assimilation system performance*

- Forecast **R**- and **B**-sensitivities can provide guidance toward the real covariance matrices.

- The combined **R**- and **B**-sensitivity analysis may show if background information is being over (or under) weighted. In the ECMWF case it appears the EDA based background errors are currently overweighting the background.

Thank you!

Questions?