Can the assimilation of atmospheric tracer in the CAMS system improve the weather forecast?

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Abstract

The operational data assimilation system of the European Centre for Medium-Range Weather Forecasts (ECMWF) is based on a 4D Var algorithm. As part of the Copernicus Atmosphere Monitoring Service (CAMS) managed by ECMWF, the ability to assimilate atmospheric tracers was included in the ECMWF 4D Var. This allows CAMS to produce daily analyses and forecast of aerosols, reactive gases and greenhouse gases relying on the assimilation of data from various satellites. The transport of the atmospheric tracers benefits from the meteorological analysis but there is currently no direct coupling in the assimilation between the atmospheric tracers and the meteorological variables.

An experimental ensemble Kalman filter (EnKF) is in development at ECMWF [1]. In the EnKF framework, the coupling between the atmospheric tracers and the meteorological variables is accounted for by the covariances of the background error. This poster presents how the assimilation of retrieval products of two of the most important anthropogenic long-lived greenhouse gases, i.e. carbon dioxide (CO_2) and methane (CH_4), modifies the meteorological analysis.

Experiments configurations

✓ EnKF, resolution Tl1159L137, 50 members, 6-h assimilation window

✓ Control experiment (**CTR**): no assimilation of CO_2 nor CH_4 data

✓ New experiment (**GHG**) with the assimilation of:

- ✗ Greenhouse Gases Observing Satellite (GOSAT) data
  - Lower tropospheric sensitivity
  - XCO_2 over land from University of Bremen
  - XCH_4 from SRON Netherlands Institute for Space Research
- ✗ Infrared Atmospheric Sounding Interferometer (IASI) data
  - Middle tropospheric sensitivity
  - XCH_4 and XCO_2 from Laboratoire de Météorologie Dynamique
  - XCO_2 in the tropical region only

✓ Period: November 2014 (+ one month spin-up period)

GHG analysis

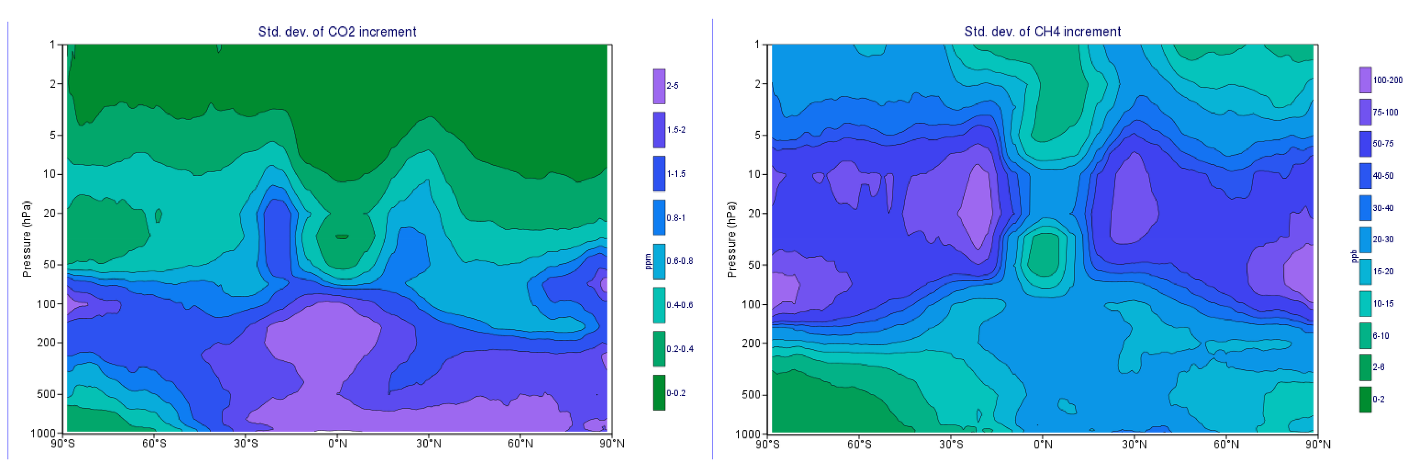

Figure 1: Zonal mean of CO_2 (left) and CH_4 (right) increment standard deviation for the month of November 2014.

✓ Assimilation of CO_2 data

- ✗ Highest variability in the tropics up to the tropopause
- ✗ High variability in the lower troposphere of the northern hemisphere associated with the variability of the emissions over land

✓ Assimilation of CH_4 data

- ✗ Highest variability in the middle stratosphere at high latitudes due to the strong CH_4 vertical gradient associated with large transport variability
- ✗ In the lower troposphere, highest variability in the northern hemisphere

Cross correlations

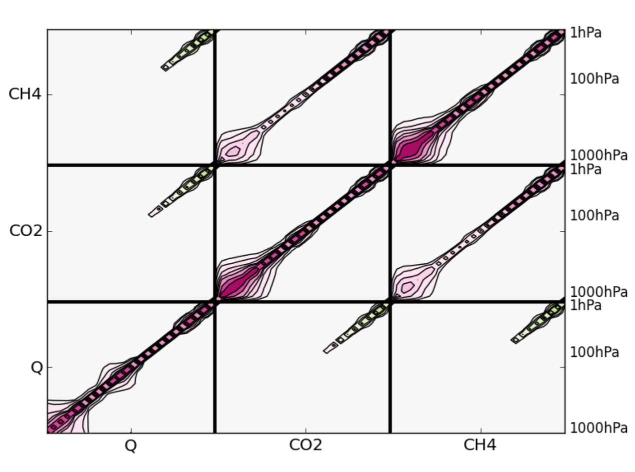

Figure 2: Example of cross correlations between Q, CO_2 and CH_4.

✓ Cross correlations:

- ✗ Between the background error of the control variables
- ✗ Background error estimated with the 6-h forecasts

✓ Control variables:

- ✗ Temperature (T)
- ✗ Specific Humidity (Q)
- ✗ Divergence (D)
- ✗ Relative Vorticity (Vo)
- ✗ Carbon monoxyde (CO_2, for **GHG** experiment only)
- ✗ Methane (CO_2, for **GHG** experiment only)

The strongest correlation found between GHG variables and meteorological variables are found for the humidity(Q) and in the stratosphere. There the correlations of the background error between CO_2/CH_4 and Q have values between -0.6 and 0

Impact on the meteorology fields

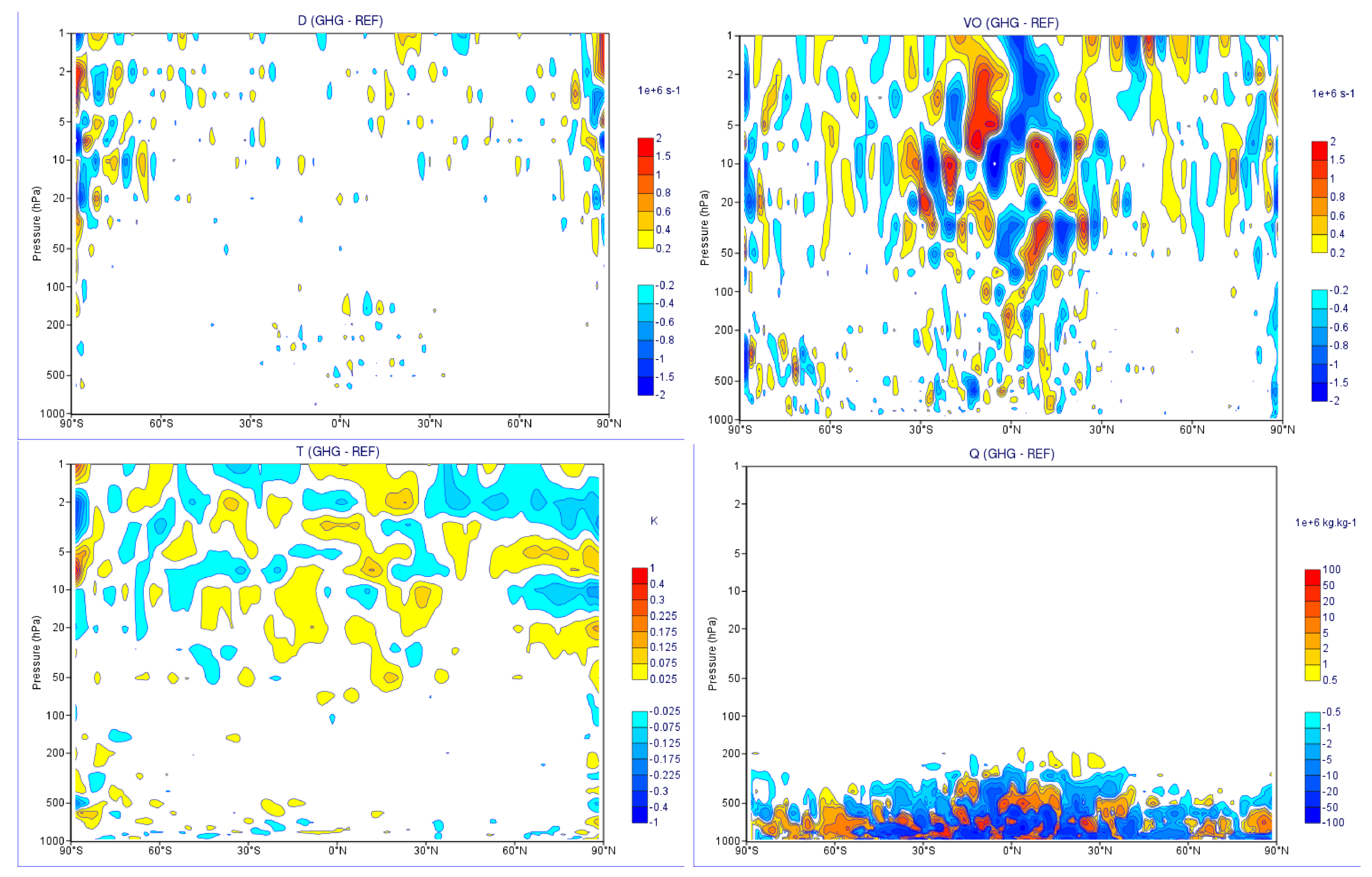

Figure 3: Zonal and monthly mean of the difference between **GHG** and **CTR** experiments for the control variables.

✓ More impact on the divergence than on the relative vorticity

✓ No change in the mean temperature in the troposphere

✓ Main impact on the humidity in the lower troposphere

Impact on the scores

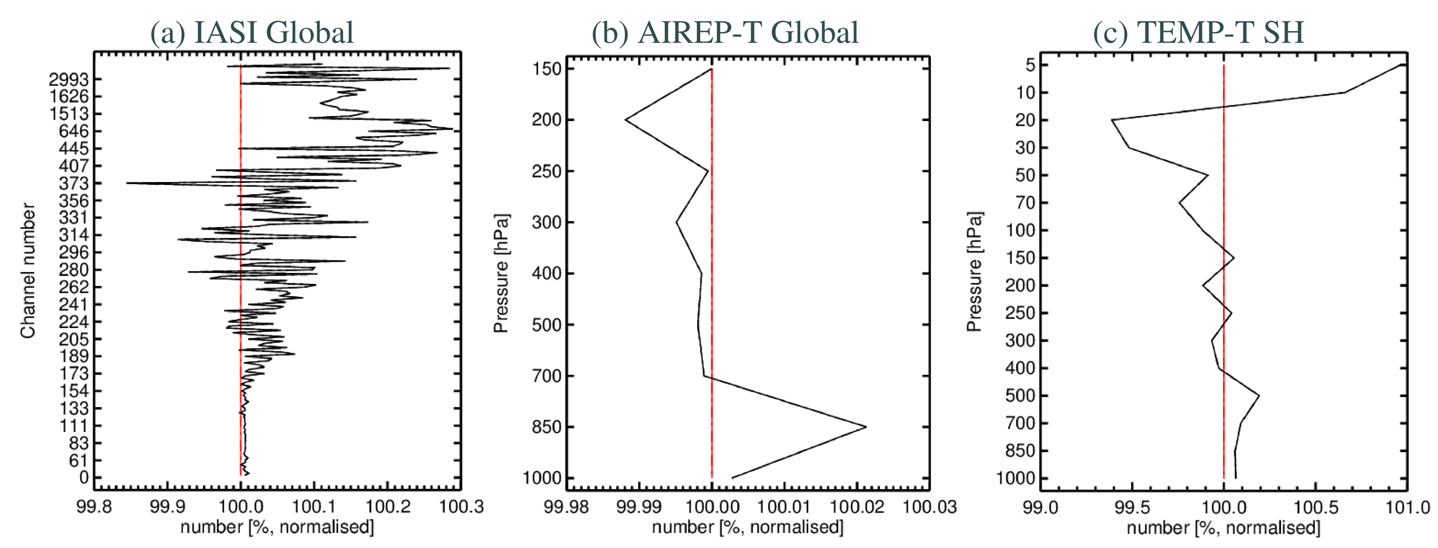

Figure 4: Normalised change in number of assimilated observations. – CTR (=100%). – GHG.

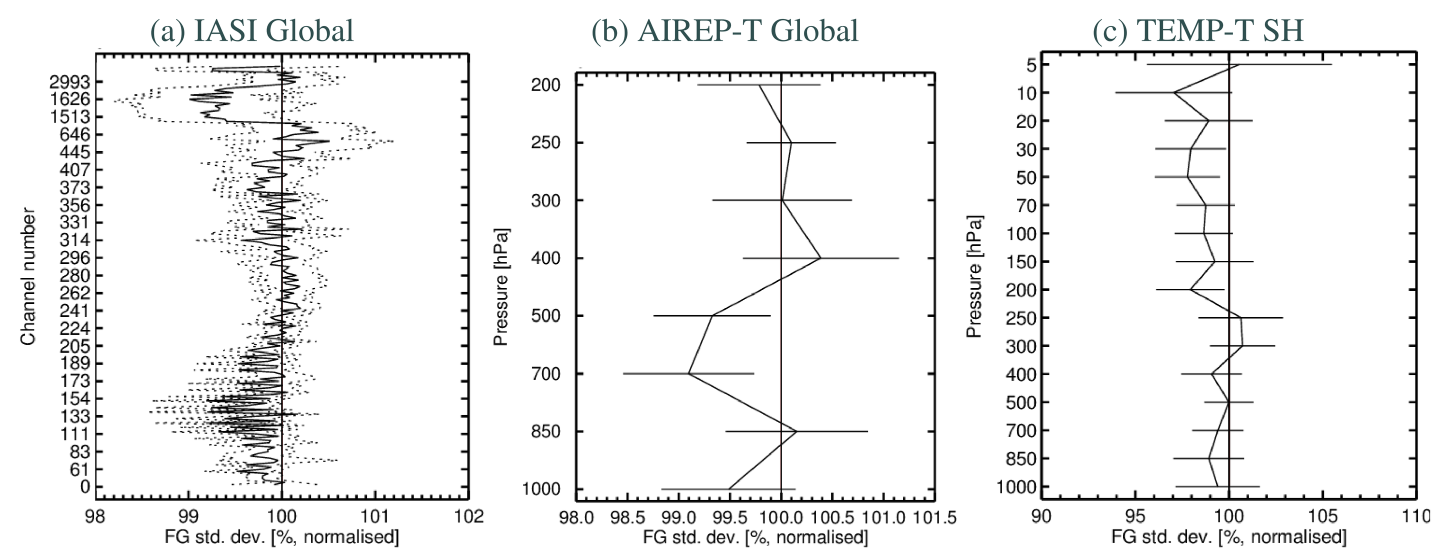

Figure 5: Normalised change in standard deviation of the first guess departure. **GHG** better than **CTR** when <100%.

✓ Slight increase of the number of assimilated satellite data in **GHG** (e.g. Fig. 4a)

✓ Slight decrease of the number of assimilated conventional data in **GHG** (e.g. Fig. 4c)

✓ Small but significant improvement of the standard deviation of the first guess departure with most of satellite data (e.g. Fig. 5a)

✓ Small but significant improvement for the temperature globally against AIRcraft REPorts (AIREPS, Fig. 5b) and in the southern hemisphere (SH) against conventional data (Fig. 5c)

✓ No significant improvement/degradation for humidity (not shown)

✓ Preliminary results: needs more validation and a longer time period

References

[1] Mats Hamrud, Massimo Bonavita, and Lars Isaksen. EnKF and Hybrid Gain Ensemble Data Assimilation. Part I: EnKF Implementation. *Monthly Weather Review*, 143(12):4847–4864, 2015.

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