Advanced tropospheric ozone monitoring by data fusion and assimilation

C. Tirelli [(1)], U.Cortesi[(1)], S. Del Bianco[(1)], S. Ceccherini[(1)], N. Zoppetti[(1)], R. Dragani[(2)], M. Bonazountas[(3)], C. Tsiakos[(3)], E. Simeone[(4)], A. Keppens[(5)], J-C. Lambert[(5)], M. van Roezendael[(5)], J. van Peet[(5)], R. van der A[(5)], E. Loenen[(6)], K. Verberne[(7)], A. Arola[(8)], J. Kujanpaa[(8)]

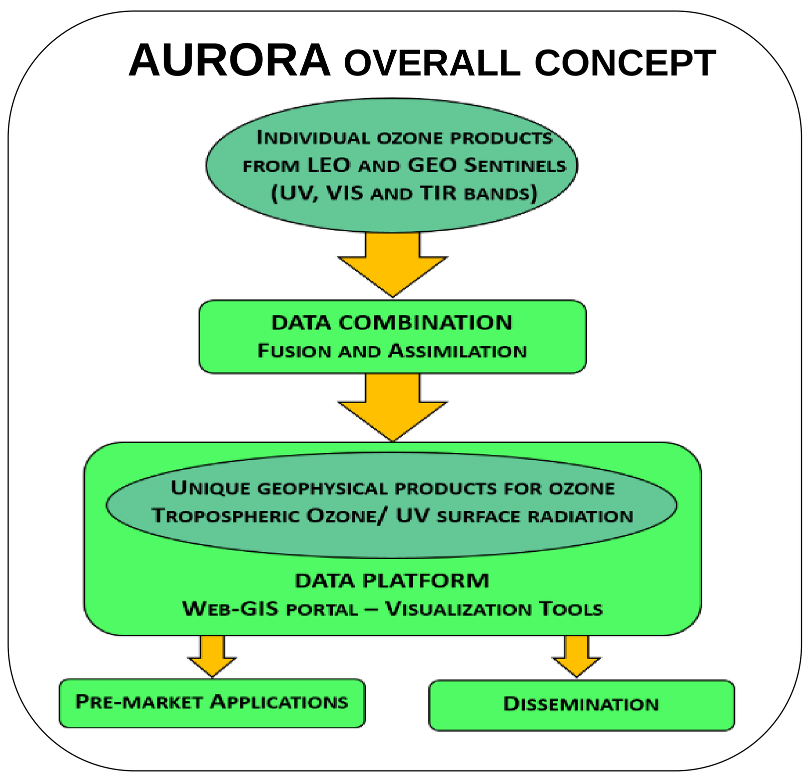
AURORA CONSORTIUM: [(1)] Istituto di Fisica Applicata "Nello Carrara", IFAC-CNR, IT; [(2)] European Centre for Medium Range Weather Forecast, ECMWF; [(3)] Epsilon International SA, GR; [(4)] Flyby Srl, IT; [(5)] Belgian Institute for Space Aeronomy, BIRA-IASB; [(6)] Science and Technology BV, NL; [(7)] Datacraft, NL. [(8)] Finnish Meteorological Institute, FMI, FIN; [(9)] Royal Netherlands Meteorological Institute, KNMI, NL

The AURORA Project

AURORA is a three-year project proposed in response to a Call of the **Horizon 2020** (EO-2-2015 Stimulating wider research use of Copernicus Sentinel Data)
Project Coordinator: Istituto di Fisica Applicata «Nello Carrara», IFAC-CNR, Italy (U.Cortesi@ifac.cnr.it) **AURORA web-site: http://www.aurora-copernicus.eu**

Scope and objectives of the project

The idea at the core of AURORA is the exploitation of advanced products for **TROPOSPHERIC OZONE** and **UV SURFACE RADIATION** derived from GEO (S-4) and LEO (S-5, S-5p) platforms, based on **ASSIMILATION OF FUSED DATA** from different spectral regions (UV, Visible, Thermal IR).



Scientific objectives

- investigate the potential of data fusion and data assimilation to convey complementary information content of measurements by the atmospheric Sentinel LEO and GEO missions into unique geophysical products.
- to focus the exploitation of the synergy between simultaneous and independent measurements of the same target on **tropospheric O_3** and **UV SURFACE RADIATION**.

Technological objectives

- to reduce the complexity of managing the high volume of Copercnius S-4 and S-5 data and increase its quality
- to develop a prototype data processing system and demonstrate its capability to work with simulated data as close as possible to the operational environment.

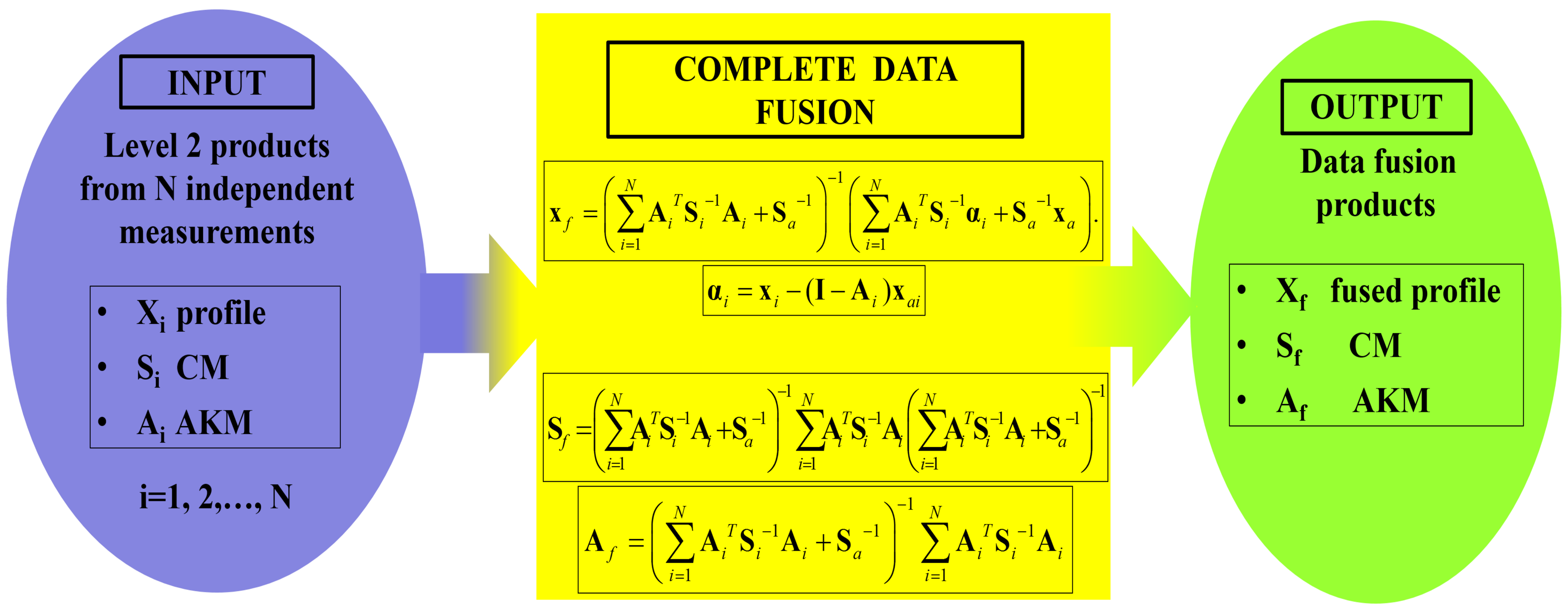
Application objectives

- to develop **two operational downstream services** (innovative mobile App for UV dosimetry and tropospheric ozone monitoring application for prediction of air quality)

Data Fusion

Data fusion is used to reduce the complexity of processing the huge amount of Sentinel data with minimum loss of information (i.e reducing the number of vertical profiles to assimilate).

The **Complete Data Fusion** (CDF) [1] method will be applied.

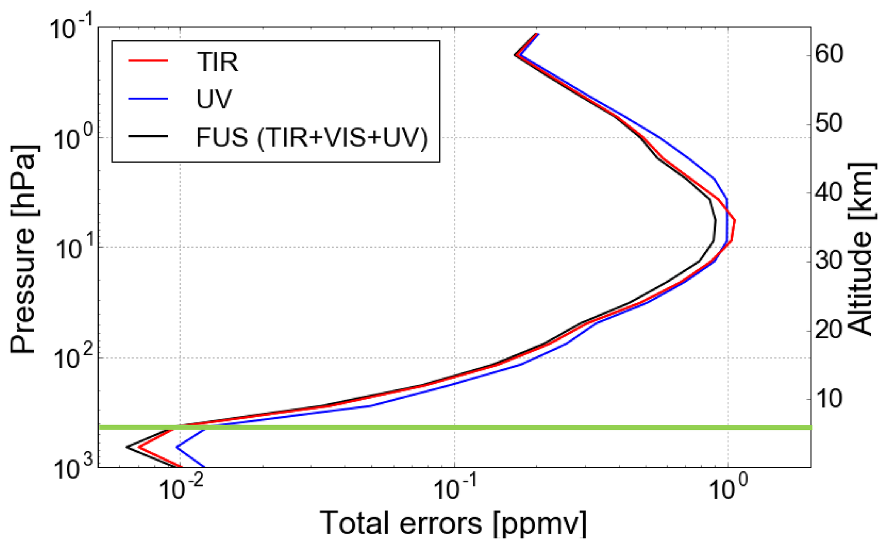


The **CDF** algorithm:

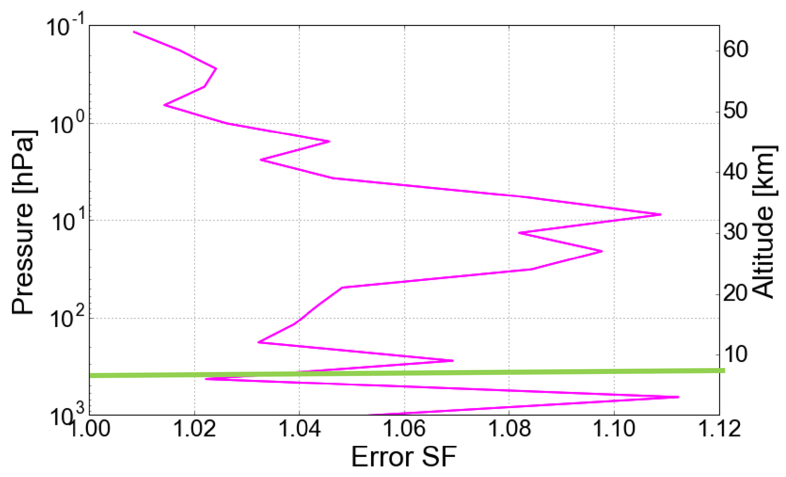
- takes into account both the covariance matrix (CM) and the averaging kernel matrix (AKM) of the profiles to be fused;
- provides results equivalent to those of the simultaneous retrieval;
- uses standard retrieval products and has very simple implementation requirements.

Ozone Profile

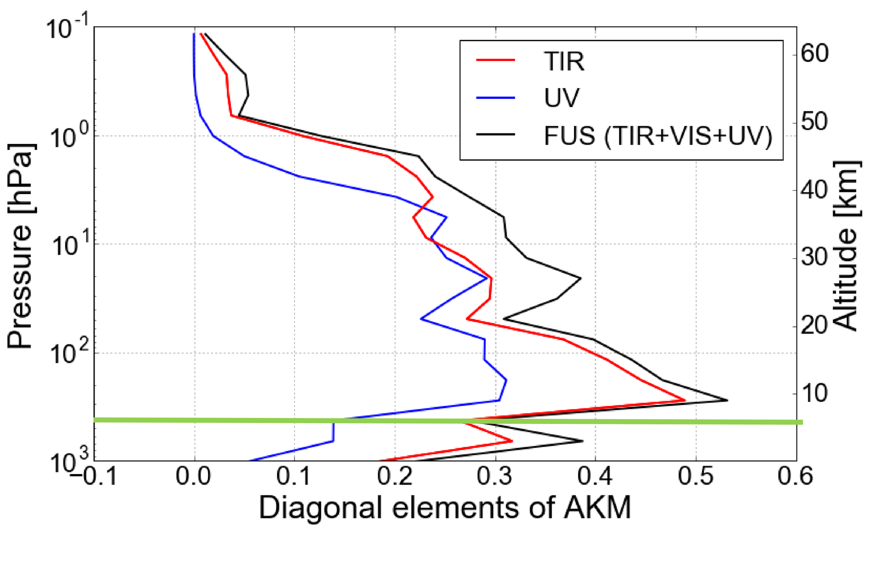
The CDF method has been used to fuse ozone profiles retrieved from simulated measurements in the TIR, VIS and UV spectral regions of Sentinel 4 (same space-time locations). Fused data shown here are simulated measurements of the first week of April 2012 (23881 analyzed pixels).



***Average total errors** of the ozone profiles obtained from TIR (red line) and UV measurements (blue line) and from the data fusion (black line). The selected tropopause altitude is shown in green*



Average error SF



Average of the diagonal elements of the AKMs

For each pressure level the error synergy factor (SF) is defined as:

$$SF_{err} = \frac{Min_{i=1,\dots,N}\,\sigma_{i,tot}}{\sigma_{f,tot}}$$

SF >1 synergy among sources of information

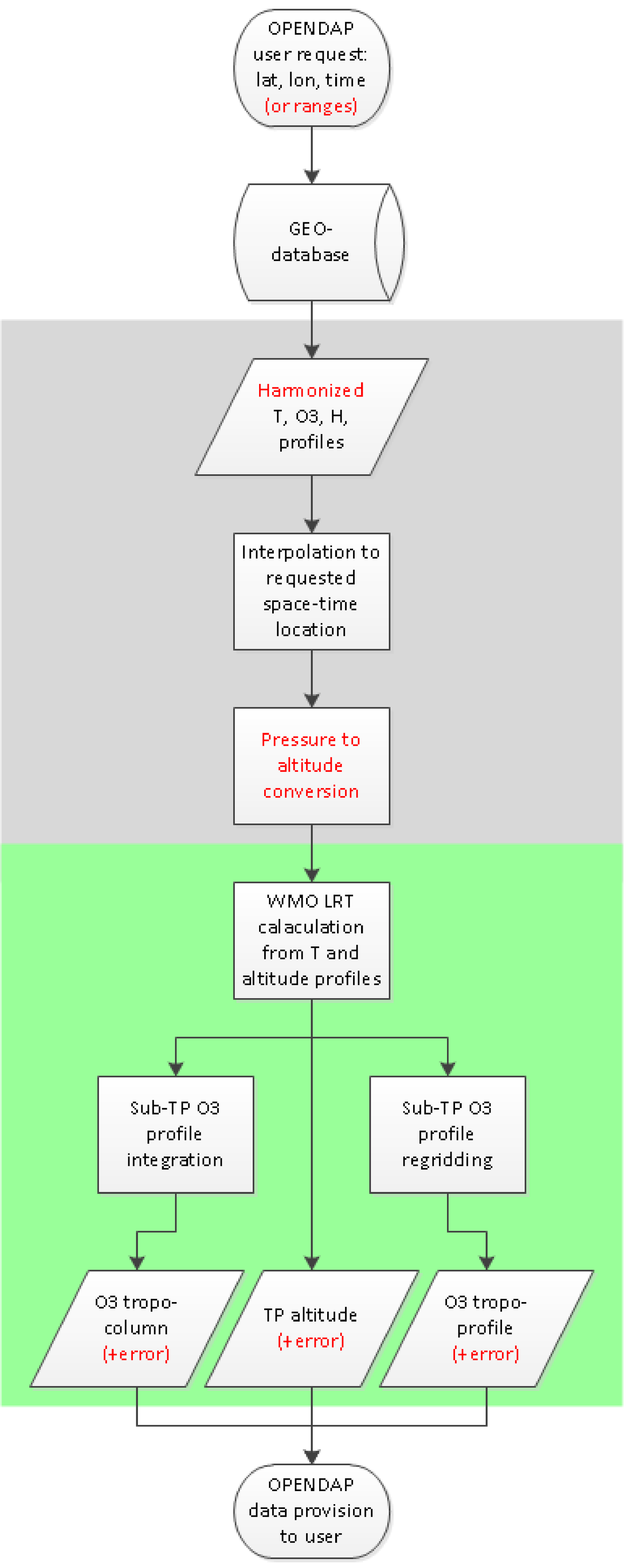
$\sigma_{i,tot}$ = total error of the *i-th* profile to be fused
$\sigma_{f,tot}$ = total error of the fused profile

Spectral range	TIR	UV	FUS (TIR+VIS+UV)
Number of DOF	4.9	3.4	5.8

*Average number of **degrees of freedom (DOF)** of TIR, UV and fused measurements.*

Tropospheric Ozone Calculation

- Read altitude, temperature, and ozone profiles from a selected latitude, longitude, time, and DAS data source.
- Horizontal and temporal interpolation and pressure to altitude conversion by the prototype Data Processor if necessary.
- Determine tropopause (TP) altitude from the temperature and altitude profiles using a fixed altitude (here at 6 km in agreement with Ozone-CCI practice) or the WMO lapse-rate tropopause definition. This requires a sufficiently fine-gridded vertical dimension of the order of 1 km [2-3].
- Convert the ozone profile below the tropopause to partial column density units.
- Integrate the tropospheric ozone column by direct summation over the partial column values below the tropopause.



Spectral range	TIR	UV	FUS (TIR+VIS+UV)
Number of DOF below TP	0.8	0.3	0.9

*Average number of **degrees of freedom (DOF) below 6 km** of TIR, UV and fused measurements.*

Conclusions

The AURORA project envisages a breakthrough in atmospheric ozone sounding, in terms of improved accuracy and vertical resolution in the troposphere, by means of the development of new innovative data fusion and assimilation techniques. The CDF method has been applied to a simulated Sentinel 4 dataset as a first step for the exploitation of the of the synergy between ozone measurements covering a wide range of spectral regions from the UV to the TIR. The first results show the improvement achieved in the profile and partial column retrieval of this greenhouse gas and sustain the potential benefits resulting from assimilation of fused data.

References

[1] Ceccherini et al., 2015: Equivalence of data fusion and simultaneous retrieval, Optics Express, 23 , 8476- 8488.
[2] WMO (1957), Meteorology – a three-dimensional science: Second session of the Commission for Aerology, WMO Bulletin, vol. IV, no. 4, 134-138.
[3] Reichler, T., M. Dameris, and R. Sausen (2003), Determining the tropopause height from gridded data, Geophys. Res. Lett., 30(20), 2042, doi:10.1029/2003GL018240.