A novel approach to synergistic exploitation of atmospheric Sentinels data

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The AURORA Project

The **AURORA** (Advanced Ultraviolet Radiation and Ozone Retrieval for Applications) project was proposed in response to a Call of the **Horizon 2020** framework programme of the EU and after positive evaluation started on February 1°, 2016.

Topic: EO-2-2015 Stimulating wider research use of Copernicus Sentinel Data.

AURORA Scope and Objectives

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

- to investigate the potential of data fusion and data assimilation to convey complementary informatiion 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 SURF. RADIATION**.

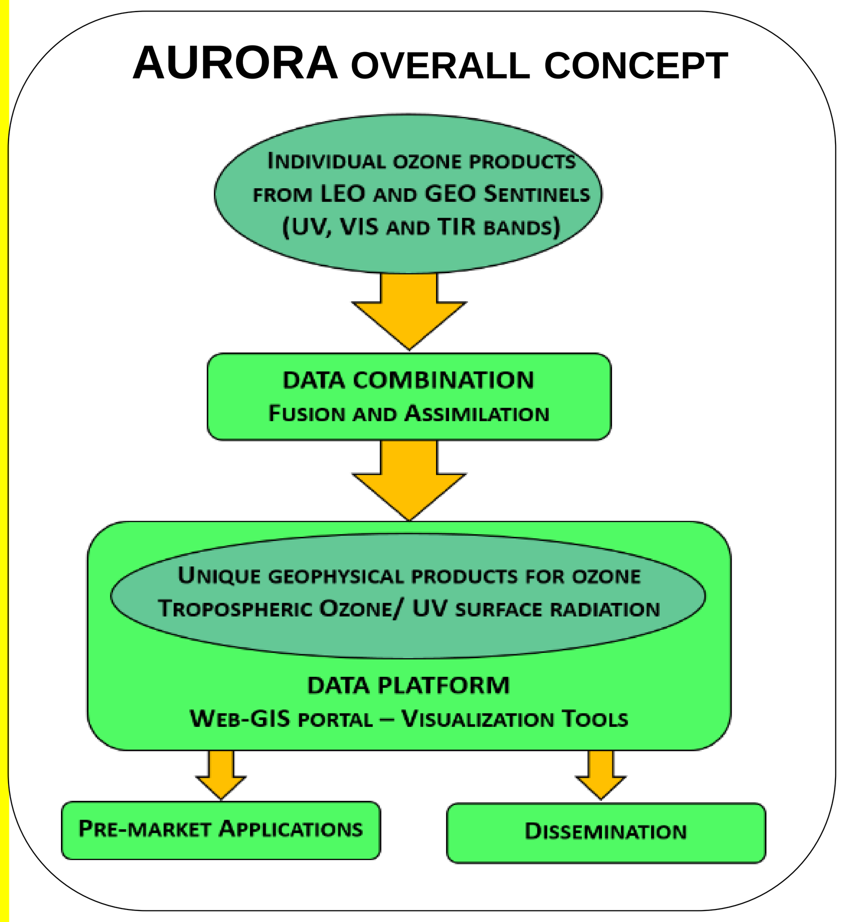
TECHNOLOGICAL OBJECTIVES

- to reduce the complexity of managing the high volume of Coperncius S-4 and S-5 data and increase its quality w.r.t. the operational outcome of individual instruments.
- to develop a prototype data processing system and demonstrate its capability to work with simulated data as closely 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 major cities and regional prediction of air quality)

AURORA Core Elements



Data Fusion of information retrieved from sensors onboard the same missions

Data Assimilation combining LEO and GEO fused profiles.

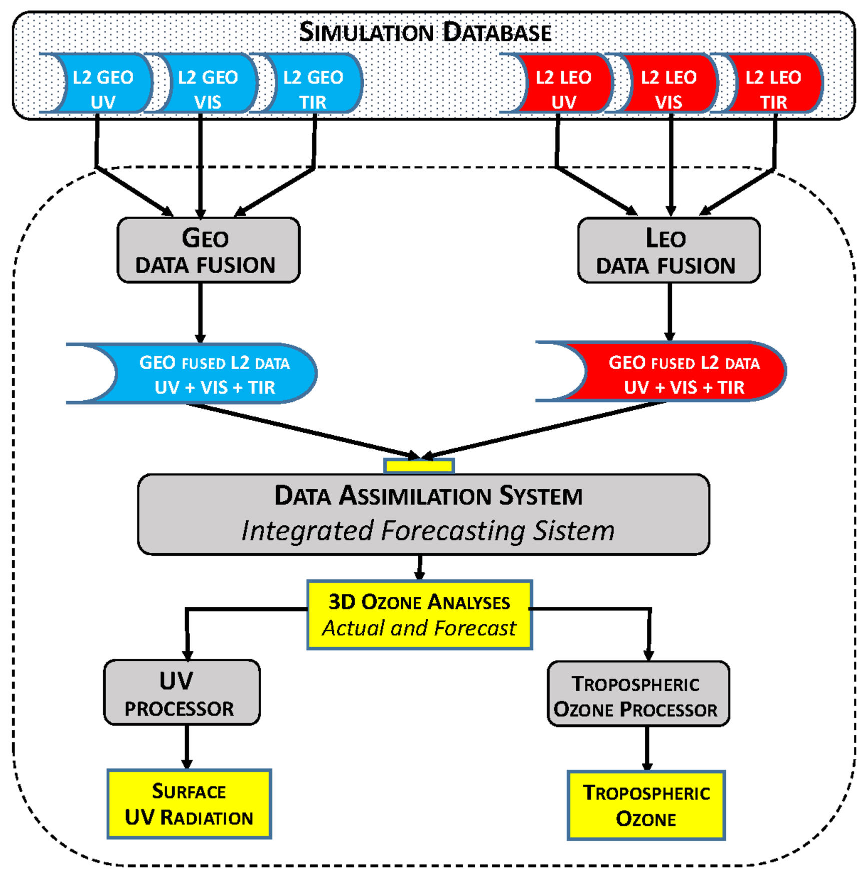
DAS available to AURORA:

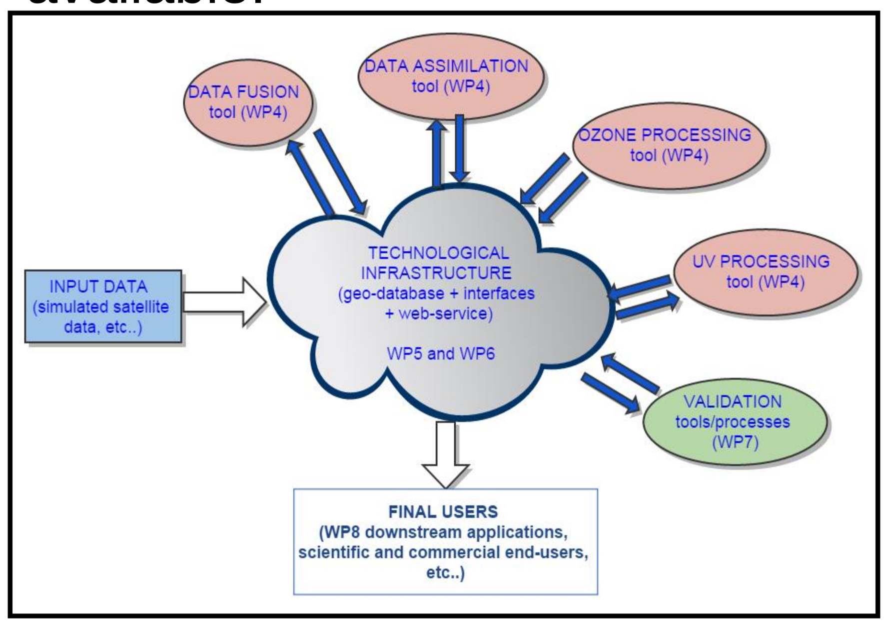
- ECMWF Integrated Forecasting System (IFS)
- KNMI Chemical Transport Model DAS (TM5)

AURORA DATA PROCESSING CHAIN

The DPC can be segmented in the **Input Data Source** (IDS) and in the **Prototype Data Processor** (PDP).

The IDS block will be fully replaced by S-4 and S-5 data once the real data become available.





INFRASTRUCTURE

From an operational point of view, the data processing is executed in the AURORA infrastructure framework using a cloud-based architecture

APPLICATIONS - Development of innovative products and services during and after project lifetime (two applications for **OZONE MONITORING IN URBAN AREAS** an **PERSONAL UV DOSIMETRY**)

DATA FUSION method

In the data fusion approach, independent vertical profiles are retrieved from the observations of two or more instruments that observe the same portion of the atmosphere in ***different spectral region or with different geometries*** and subsequently ***combined through a specific algorithm into a single estimate.***

We present herewith the new data fusion method used in the project to combine the information associated to the operational products of the LEO instruments, as well as to the ones on the GEO mission.

- We suppose to have N independent simultaneous measurements of the vertical profile of an atmospheric species referred to the same geolocation.
- Performing the retrieval of the N measurements we obtain N vectors $\hat{\mathbf{x}}_i$ (i=1, 2, …, N) that provide independent estimates of the profiles on a common vertical grid. These vectors are characterized by the covariance matrices (CM) S_i and the averaging kernels (AKM) A_i.
- Exploiting the definition of AKM, we can expand at the first order the relationship that exists between retrieved profile and true profile:

$$\hat{\mathbf{x}}_i = \mathbf{x}_{ai} + \mathbf{A}_i \left(\mathbf{x}_{true} - \mathbf{x}_{ai} \right) + \boldsymbol{\sigma}_i$$

x_{ai}: a priori profile used in the i-th retrieval, x_{true}: true profile, σ_i : errors on $\hat{\mathbf{x}}_i$

- Rearranging we obtain:

$$\boldsymbol{\alpha}_i \equiv \hat{\mathbf{x}}_i - \left(\mathbf{I} - \mathbf{A}_i \right) \mathbf{x}_{ai} = \mathbf{A}_i \mathbf{x}_{true} + \boldsymbol{\sigma}_i$$

- Since the vectors α_i are measurements of x_{true}, we can perform a simultaneous fit of these measurements minimizing the following cost function:

$$c(\mathbf{x}) = \sum_{i=1}^{N} \left(\boldsymbol{\alpha}_i - \mathbf{A}_i \mathbf{x} \right)^T \mathbf{S}_i^{-1} \left(\boldsymbol{\alpha}_i - \mathbf{A}_i \mathbf{x} \right) + \left(\mathbf{x} - \mathbf{x}_a \right)^T \mathbf{S}_a^{-1} \left(\mathbf{x} - \mathbf{x}_a \right),$$

x_a and S_a are the a priori profile and its CM that we want to use as a constraint of the fit.

- The minimum of c(x) is obtained for:

$$\mathbf{x}_f = \left(\sum_{i=1}^{N} \mathbf{A}_i^T \mathbf{S}_i^{-1} \mathbf{A}_i + \mathbf{S}_a^{-1} \right)^{-1} \left(\sum_{i=1}^{N} \mathbf{A}_i^T \mathbf{S}_i^{-1} \boldsymbol{\alpha}_i + \mathbf{S}_a^{-1} \mathbf{x}_a \right).$$

This relationship provides a new estimate of the profile determined with the data fusion of N different profiles.

- This fused profile has a CM, obtained propagating the errors of α_i into x_f, equal to:

$$\mathbf{S}_f = \left(\sum_{i=1}^{N} \mathbf{A}_i^T \mathbf{S}_i^{-1} \mathbf{A}_i + \mathbf{S}_a^{-1} \right)^{-1} \sum_{i=1}^{N} \mathbf{A}_i^T \mathbf{S}_i^{-1} \mathbf{A}_i \left(\sum_{i=1}^{N} \mathbf{A}_i^T \mathbf{S}_i^{-1} \mathbf{A}_i + \mathbf{S}_a^{-1} \right)^{-1}$$

- and an AKM, obtained performing the derivative of x_f with respect to the true profile, equal to:

$$\mathbf{A}_f = \left(\sum_{i=1}^{N} \mathbf{A}_i^T \mathbf{S}_i^{-1} \mathbf{A}_i + \mathbf{S}_a^{-1} \right)^{-1} \sum_{i=1}^{N} \mathbf{A}_i^T \mathbf{S}_i^{-1} \mathbf{A}_i$$

AURORA web-site: http://www.aurora-copernicus.eu/