AURORA Project
A challenge for synergistic exploitation of Sentinel-4/-5 ozone operational products

Ugo Cortesi (IFAC-CNR)
on behalf of the AURORA Consortium

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AURORA in a nutshell

EU Framework Program: HORIZON 2020

Research Area: Leadership in Enabling and Industrial Technologies (LEIT)
Sub-program: Space

Call: H2020-Earth Observation-2015
Topic: EO-2-2015 Stimulating wider research use of Copernicus Sentinel Data

Project Title: Advanced Ultraviolet Radiation and Ozone Retrieval for Applications
Project Duration: 36 months (February 1°, 2016 – January 31°, 2019)
AURORA website: http://www.aurora-copernicus.eu/
The AURORA Consortium

Institute for Applied Physics «Nello Carrara» (IFAC-CNR), Italy

Belgian Institute for Space Aeronomy (BIRA-IASB), Belgium

European Center for Medium Range Weather Forecast (ECMWF), UK

Finnish Meteorological Institute (FMI, Finland)

Royal Netherlands Meterological Institute (KNMI), Netherlands

Datacraft, Netherlands

Epsilon, Greece

Flyby, Italy

Science & Technology (S&T), Netherlands
The AURORA Consortium

- FMI (Helsinki, FI)
- KNMI (Amsterdam, NL)
- ECMWF (Reading, UK)
- BIRA-IASB (Brussels, BE)
- IFAC-CNR (Firenze, IT)
- S&T Corporation (Delft, NL)
- DATA CRAFT (Rotterdam, NL)
- FLYBY (Livorno, IT)
- EPSILON (Athens, EL)
Copernicus is the European Union Programme for Earth Observation implemented by the European Commission in partnership with the European Space Agency.

Copernicus aims to provide space and non-space Earth Observation data and accurate and reliable information for operational applications.

http://copernicus.eu/
Six families of «Sentinel» space mission
Form the space component of Copernicus.

**SENTINEL-1**
Mission providing all weather, day and night radar imagery for land and ocean services

**SENTINEL-2**
Mission providing high resolution optical imagery for land services

**SENTINEL-3**
Mission providing high accuracy optical, radar and altimetry data for marine and land services

**SENTINEL-4**
Geostationary mission for atmospheric monitoring

**SENTINEL-5**
Low earth Orbit for atmospheric monitoring

**SENTINEL-6**
Radar altimeter for observation of the topography of the global ocean
«Sentinel» missions

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The atmospheric Sentinel missions

The atmospheric Sentinel missions aim at filling the gap of ongoing operational missions, as GOME-2 and IASI (MetOp) or OMPS and CRISS (JPSS):

- **High spatial resolution** (higher number of «cloud-free» pixels)
- **High temporal resolution**
- **High precision**

Comparison of spatial resolution of Sentinel-5 with respect to previous missions (ESA image)

**Sentinel-5p**

**Sentinel-4**

**Sentinel-5**

**Launch date 2006**

**Launch date 2002**

**Launch date 2004**

**Launch date 2021**
**GEOstationary (GEO)**
- Hourly revisit time over Europe
- Mainly Air Quality
- Diurnal cycle of tropospheric composition

→ **Sentinel-4**

**Low Earth Orbit (LEO)**
- Daily revisit time global coverage
- Climate, air quality, ozone and UV
- Tropospheric and stratospheric composition

→ **Sentinel-5**

→ **Sentinel-5 Precursor**

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**European Space Agency**
AURORA: Objectives of the project

**SCIENCE**

- to investigate the **potential of data fusion and assimilation** to convey complementary information of the atmospheric Sentinels measurements into unique geophysical products
- to focus the **exploitation of the synergy** between simultaneous and independent measurements of the same target on **tropospheric O3** and **UV surface radiation**

**TECHNOLOGY**

- to **reduce the complexity** of managing the high volume of Copernicus 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**

- To develop **two operational downstream services** (innovative mobile App for UV dosimetry and tropospheric ozone monitoring application for prediction of air quality)
AURORA
The overall concept
Atmospheric Scenario and Data Simulation

**Atmospheric scenarios** ➔ definition of the state of the atmosphere for forward calculation and generation of S4 and S5 synthetic measurements (ECMWF).

Atmospheric scenario (4 months of data) are generated from the **MERRA 2** re-analysis, provided by GMAO at NASA Goddard Space Flight Center.

**Sentinel-4 and Sentinel-5 data simulation**

- LEO and GEO UV L2 products for Ozone and associated VCMs and AKMs (FMI, with contributions from KNMI).
- LEO and GEO VIS L1 and L2 data for Ozone and associated VCMs and AKMs (BIRA-IASB, with contributions from KNMI).
- LEO and GEO TIR L2 products for Ozone and associated VCMs and AKMs (IFAC-CNR).
Data Fusion

Combination of LEO+LEO, GEO+GEO (and LEO+GEO) coincident and independent measurements of the same target acquired in different spectral regions (UV, VIS and TIR).

Method: Complete Data Fusion (Ceccherini et al., Equivalence of data fusion and simultaneous retrieval, *Optics Express*, 23, 7, 8476-8488. 2015)

Simultaneous retrieval versus data fusion.

Equivalence of simultaneous retrieval and complete fusion
In a linear approximation, the solution obtained with complete fusion coincides with the solution obtained with simultaneous retrieval.
First results of CDF method applied to Sentinel-4 UV, VIS, TIR data fusion

Simulated S-4 data for the atmospheric scenario from the 1st week of April 2012.
Total number of pixel analysed = 30,000 (approx.)
Number of fused UV+TIR+VIS = 99% of the total,
Number of fused UV+TIR = 1% of the total

**LEFT PANEL**
Average Ozone profile obtained from:
- TIR measurements
- UV measurements
- Data fusion
- True values

**RIGHT PANEL**
Average difference w.r.t. the values of the true profile of:
- TIR measurements
- UV measurements
- Data fusion

Continue … ➔
First results of CDF method applied to Sentinel-4 UV, VIS, TIR data fusion

Average total errors of the Ozone profile obtained from:
- TIR measurements
- UV measurements
- Data fusion

Average of the number of Degrees Of Freedom of the TIR, UV and Fused profiles.
On average, the fused profile has 0.9 DOFs more than the TIR profile and 2.4 DOFs more than the UV profile.
Data Assimilation

State-of-the-art Data Assimilation Systems (DASs) will be used to combine the LEO and GEO fused profiles, and contrasted with the assimilation of standard retrievals.

Two DASs are available to AURORA:
- ECMWF Integrated Forecasting System (IFS)
- KNMI Chemical Transport Model DAS (TM5)

Output
Ozone vertical profile ➔ Tropospheric Ozone
UV Surface Radiation

Assimilation of fused products versus assimilation of standard products
AURORA Data Processing Chain
AURORA Technological Infrastructure

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

Validation Chain

- Translation of user requirements and of data/service specifications into validation requirements; conception of the Product Validation Plan (PVP).
- Performance assessment of retrieval/fusion/assimilation procedures and their resulting ozone and UV data products and associated uncertainties.
- Performance assessment of the full data processing chain and QA/validation of the final ozone and UV products using ground-based reference observations.

Applications

AURORA aims to develop two operational downstream services using innovative mobile App for **UV dosimetry** and **tropospheric ozone monitoring application for major cities and regional prediction of air quality** reaching a pre-market version at the end of the project.

Pre-market service on Urban Pollution Monitoring

[Image: Webpage link: http://www.happysun.it/]

Personal UV dosimetry
HappySun | integrated photoprotection system

Life style & Skin cancer statistics
What is AIR-Portal?

• Feasibility study both technical and economical
• Dashboard on Air Quality for both cities and citizens
• Combines various levels of monitoring data
AIR Portal and AURORA

• **Successful feasibility study:**
  - Positive technical results
  - Great interest from stakeholders
  - Business model is positive

• **AIR-Portal currently being developed into commercial service**

• **AURORA is of great benefit:**
  - Providing accurate AQ information relies on the best possible input
  - Improved O3 data products will make our service more accurate
  - In addition we can benefit from the joint market analysis
  - Finally, the expertise of the AURORA team is invaluable.
International links

Strong links with a significant number of European and non-European projects.

- Link with GEOSS (Global Earth Observation System of Systems) and CEOS (Committee on Earth Observation Satellites)
- Link with Ozone CCI (Climate Change Initiative)
- Link with FP7 smeSPIRE
- Link with TEMPO and GEMS
- Link with CAMS (Copernicus Atmosphere Monitoring Service)
Thank you for your attention!

AURORA – Advanced Ultraviolet Radiation and Ozone Retrieval for Applications.

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