

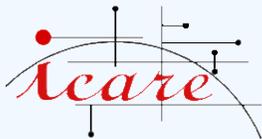


PHIDIAS

Prototype of HPC/Data Infrastructure for On-demand Services

PHIDIAS: Steps forward in detection and identification of anomalous atmospheric events from space

SPASCIA



Webinar | October 13, 2020, 15:00 CEST

Pascal PRUNET, CEO SPASCIA



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Earth and environment challenges at local, regional and global scales : continuous increase of human activities modify the atmospheric composition

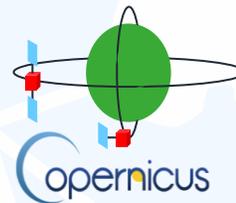
- Impact on environment (climate; soil, water and air quality; biodiversity)
- Impact on health, on economy

Needs to understand and to monitor for acting



European answers for better addressing these challenges : Europe is entering in the era of operational measurement of the air composition from space, for the analysis and forecasting of chemical weather and climate monitoring

- 4 Operational sounding instruments from 2022-2023 : Sentinel 4 and 5 onboard Metop-NG and MTG
- Copernicus Operational forecasting services for atmospheric chemistry (CAMX) and Climate (C3S)
- Development of the European capacity for the measurement of GHG for monitoring human emissions



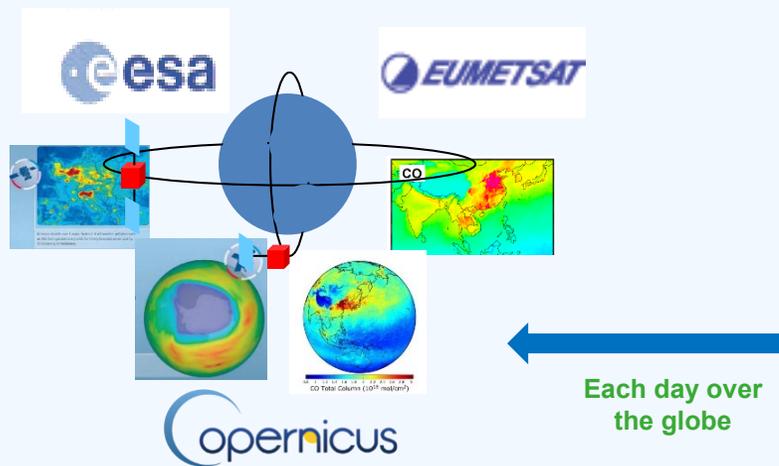
First measurements already available : IASI, GOME (Metop) Sentinel 5 precursor (S5P/TROPOMI)

From **2022**, European atmospheric sounding missions will deliver each day several TB (terabytes) of raw **datacubes at high spatial/temporal/spectral resolutions**. This represents an unprecedented amount of atmospheric data, with improved quality and coverage.



Onboard **geostationary MTG satellite**, the Sentinel-4 mission comprises an **UVN** instrument and data InfraRed Sounder (**IRS**), completed by **FCI**

Each 30 minutes over Europe



Onboard **polar-orbiting MetOp SG satellite**, the Sentinel-5 mission comprises an **UVNS** instrument and data from **IASI-NG**, **MetImage** and **3MI**

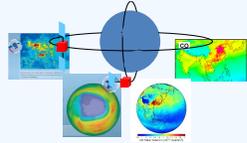


Each day over the globe

How to comprehensively deal with all available information ?

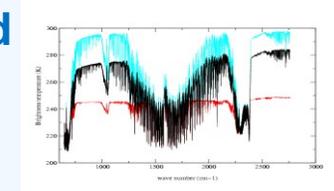
- Key challenge is to provide the capacity of intelligent screening of large amounts of satellite data for targeting scenes or events of interest in view of their dedicated processing or exploitation.

PHIDIAS addresses those needs by using HPC and HPDA capacities of intelligent **screening approaches in an operational context**, for detection and identification of atmospheric composition events.

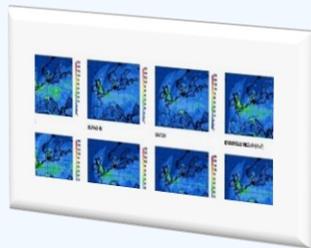


Earth observation from space is underexploited

Huge quantity of data, increasing information content and complexity



Operational forecasting systems
Efficient, real-time data assimilation in models, but could not use « extreme » data related with « extreme events »
Reduced added value of the data



Detection and Filtering in real time of relevant data



Realtime Detection & analyse of extreme events, pollutant plumes, other targeted events

Added-value :
Verification, improvement

Added-value :
Robust detection, objective filtering

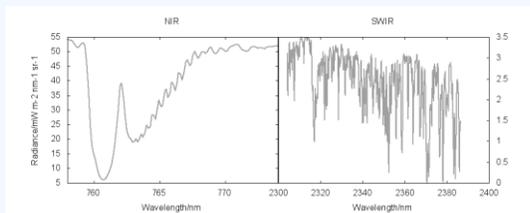


Research groups, scientific institutes
Innovative and well adapted to event studies but case by case exploitation of the data
Not exhaustive exploitation, no real-time analysis



Innovation

Dedicated services
Early warning, monitoring, decision support



L1B data



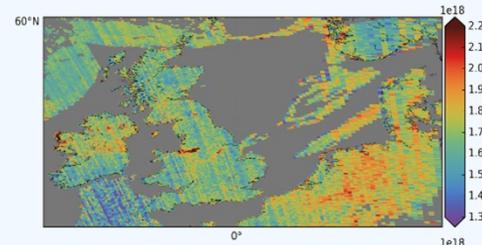
PCA-based screening of L1B data

On the flow, realtime detection & analysis of anomalous events



Catalogue/Metadata of selected and characterised L1B data

Earth observation from space Sentinel 5 Precursor (S5P) L1B, L2



L2 product



AI-based Detection of gas plume and sources from L2 products

On demand processing of the data for detection of plumes and sources over a region/period specified by the user



Processed L2 products with additional characteristics

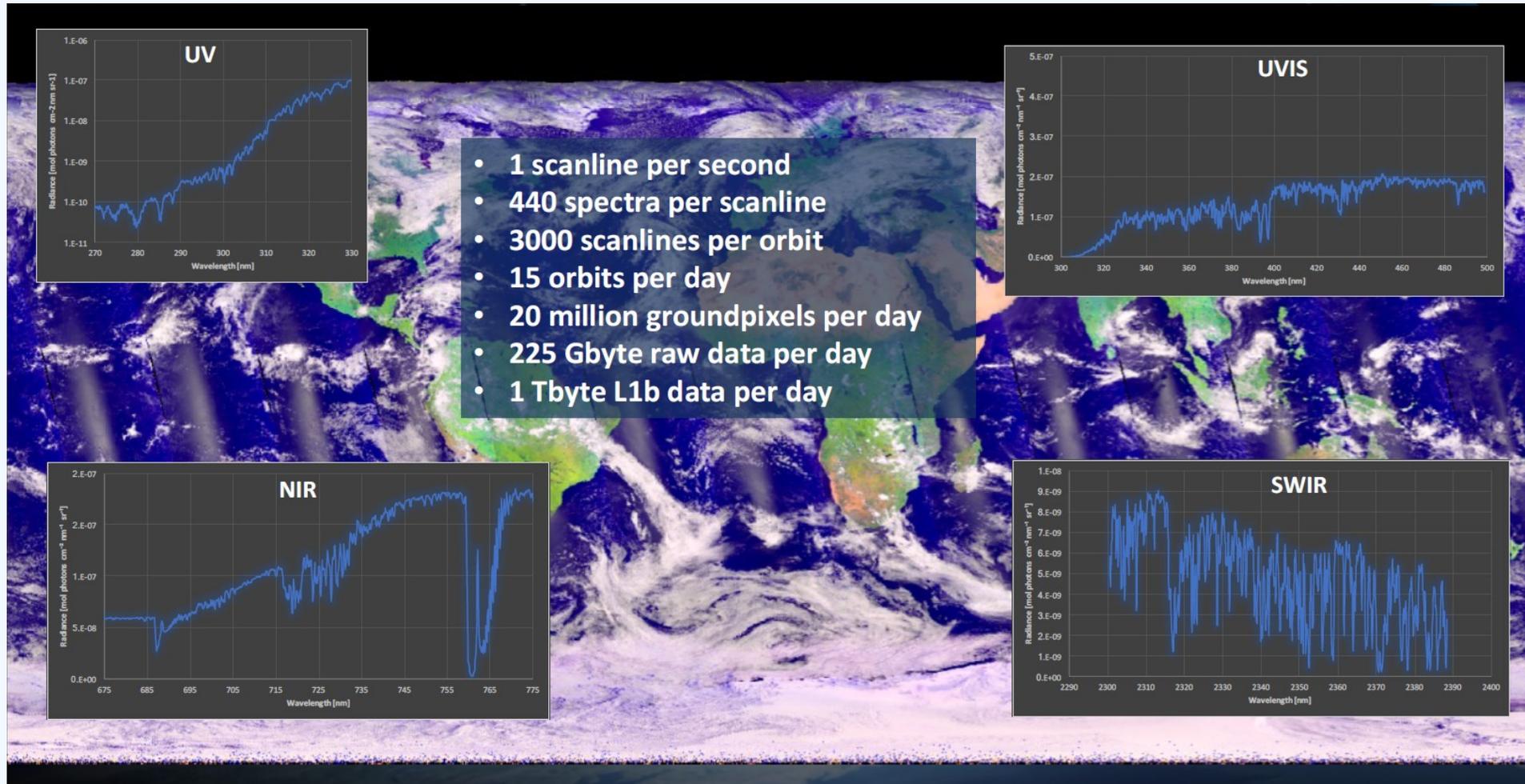


PHIDIAS Pilot users :

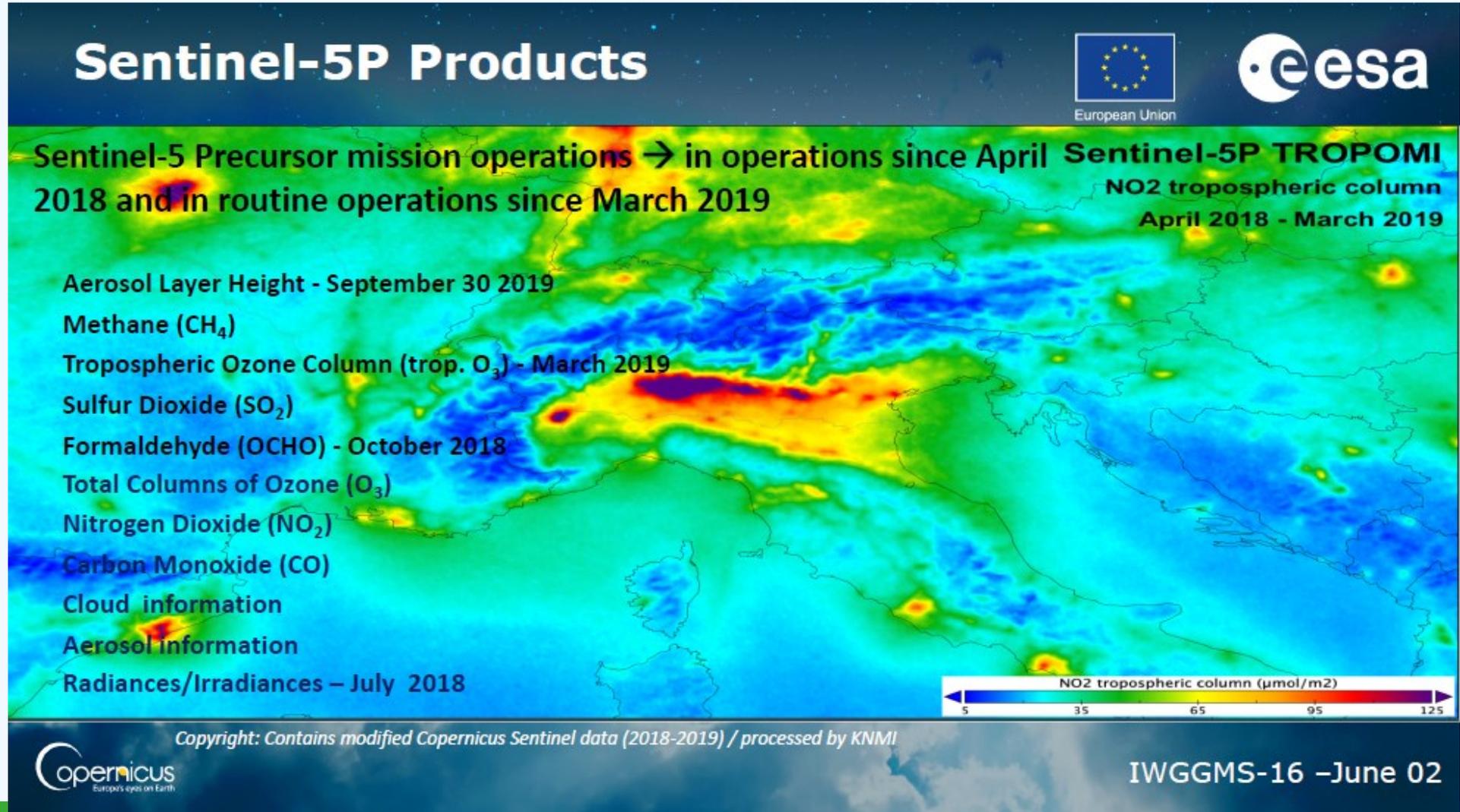


Complementary dedicated services
Early warning, monitoring, decision support

- This use case propose to develop, test and prototype the approach with Sentinel 5 Precursor data/products : Level 1 data ...



- ... and Level 2 products



Objective : intelligent screening of large amount of satellite data for detection and identification of anomalous atmospheric composition events

Two processing prototypes are addressed proposed for development and test :

- 1. PCA-based screening of L1 data (SWIR) for detection of extreme events.** Based on experience and methods developed for IASI, implementation and consolidation of algorithms and tools for generic processing of atmospheric spectra recorded by S5P.

Real-time, systematic processing of data

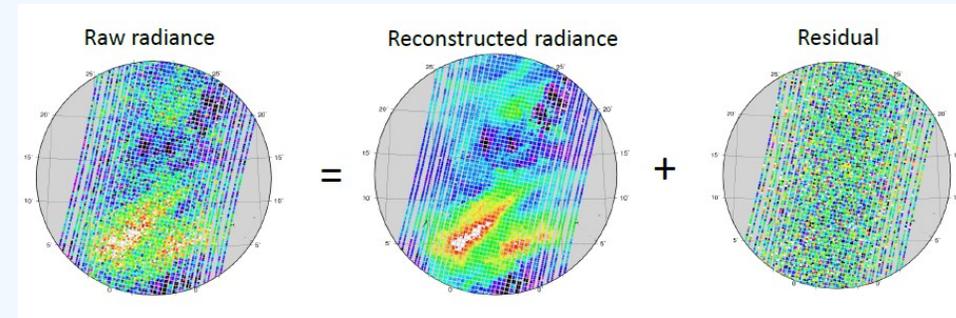
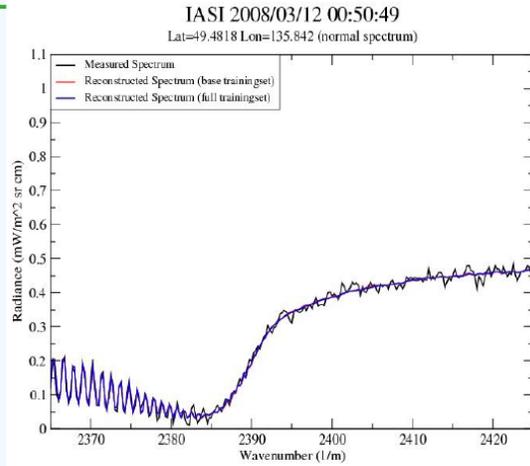
- 2. New AI methods for objective/automatic detection of plumes from L2 products (CO, CH₄, NO₂, SO₂):** dedicated AI methods based on Particle Swarm Optimisation approaches and exploiting similitude with animal behavior modelling -> comprehensive exploitation of spatial and temporal information for detecting plumes and sources.

On demand processing : historical data or real time processing

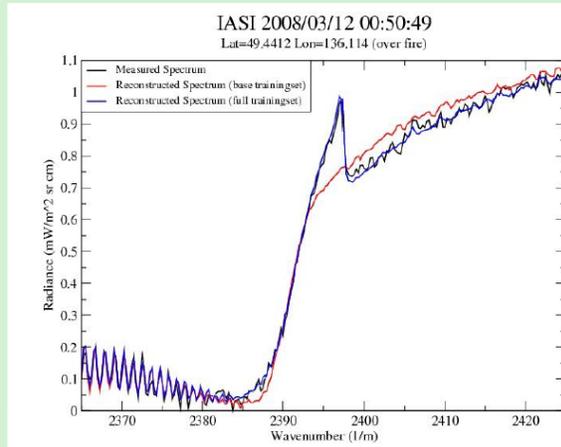


1. PCA-based screening of L1 data – Example of IASI

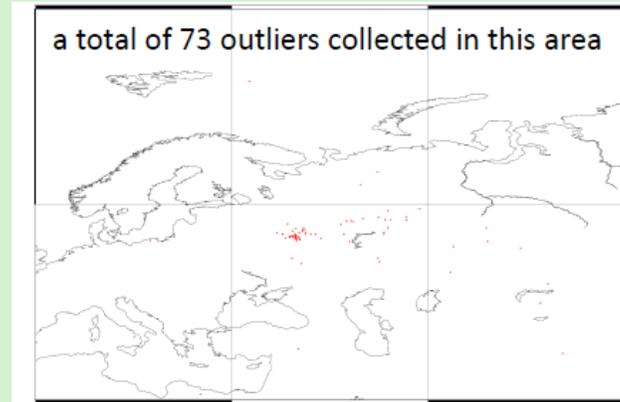
**Nominal case:
denoising filter**



**Extreme case:
identification
of the
residual
signal**



**Reconstruction of "scores" maps:
rapid detection of
anomalous situations**



**Analysis of "residuals" :
interpretation of the
anomalous event**

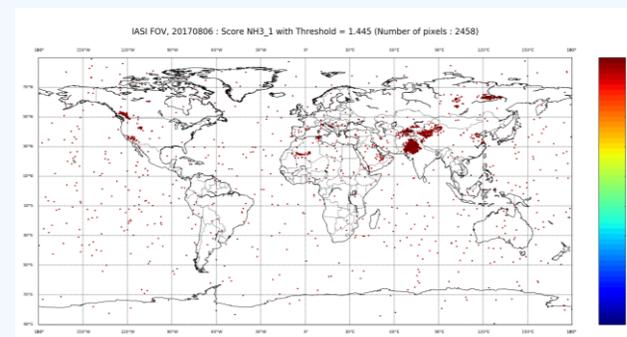


1. PCA-based screening of L1 data (SWIR) for detection of extreme events.

Status:

- 1 year, global scale of S5P Level 1 (L1) data available at ICARE
- PCA-screening processing under development (adapted from IASI-PCA developed with CNES)

- Processing already tested on IASI real data
- Development/adaptation at HYGEOS is ongoing



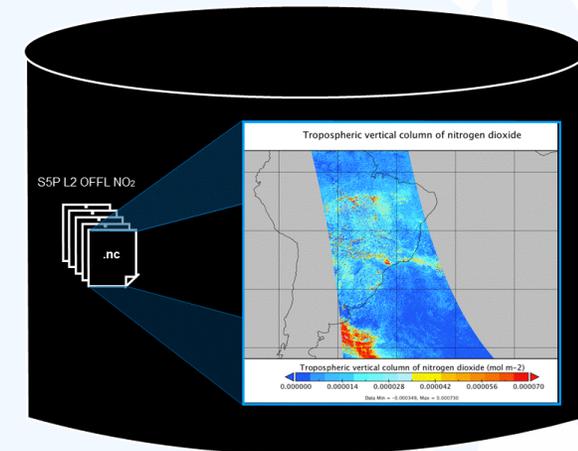
- Analysis and pre-processing of L1 ShortWave InfraRed (SWIR) spectra (bands 7 and 8) is ongoing, in order to be ingested by the PCA processing
 - Issue: complex but necessary filtering of bad pixels for exploiting the whole spectrum
 - Analysis of spectral micro-windows: indicators for detection of pollutants (air quality, greenhouse gases)

Next steps : first tests of PCA processing on small subsets of S5P data; generation of global scale database for the learning phase; implementation at ICARE for test and prototyping

2. New AI methods for objective/automatic detection of plumes from L2 products (CO, others?: CH₄ NO₂, SO₂)

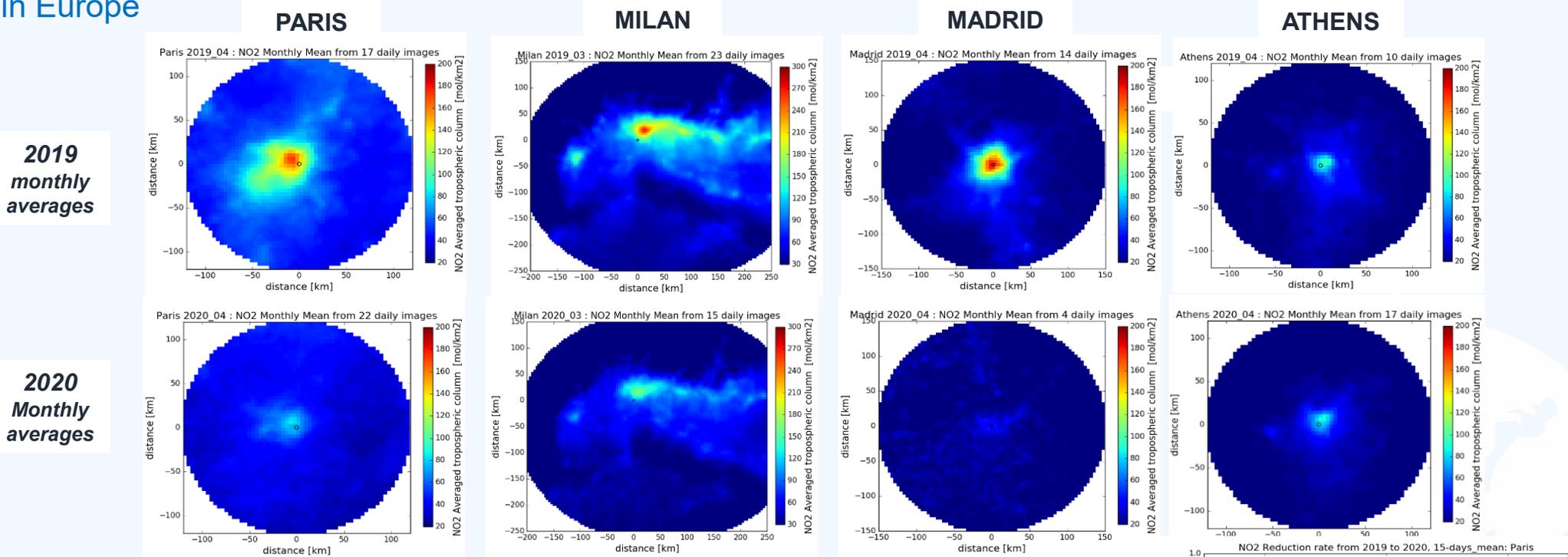
Status:

- Global S5P Level 2 products since 2018 available at ICARE
- Preparation and analysis of S5P Level 2 product (NO₂)
 - Analysis of image over pollution sources (see side results in the next slide)
 - Implementation of dedicated storage of the product, optimised for speedy retrievals given {geolocation, time} constraints over the whole dataset (2018 - present)
- Development of the AI engine for source and plume detection
 - Neural network agents, stochastic optimization process
 - Selection of data subsets for the learning phase
- Alternative method analyzing significant signal enhancements



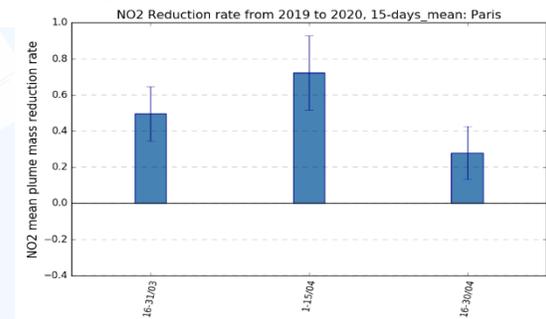
Next steps : learning phase and tests on S5P data subsets

- From ESA S5P measurements of the **air pollutant NO₂ from space**, we have assessed the impact of the human activity reduction on air pollution by comparing the first 4-months periods of 2019 and 2020 on a daily, weekly and monthly basis for 4 major cities in Europe



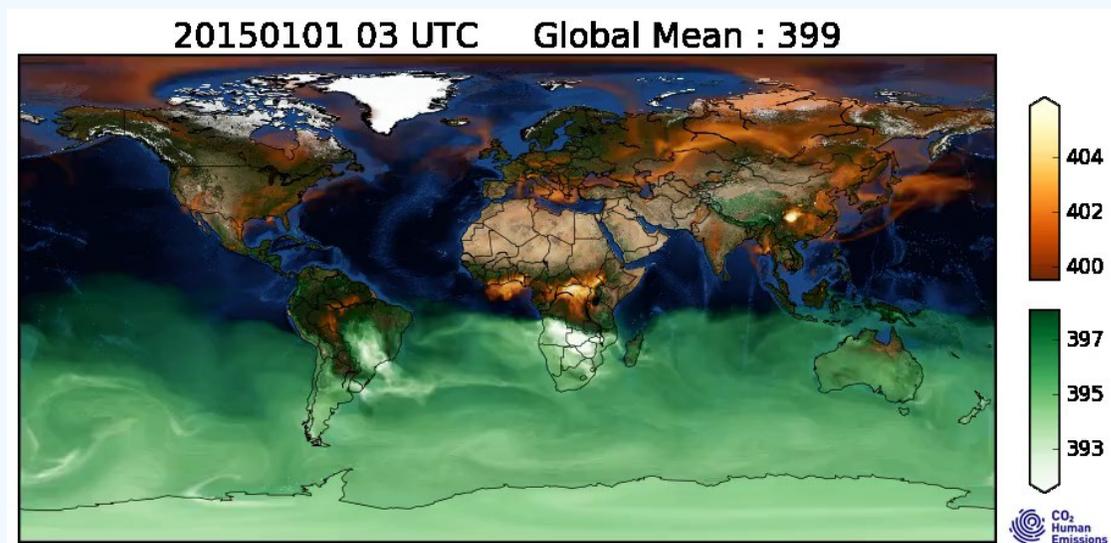
- ✓ Start dealing with the data
- ✓ Understand the information
- ✓ Show the added-value of S5P

Reductions in the pollution level (using NO₂ tropospheric column as a proxy) have been observed from Mid March and for April 2020 (52% +/-9% for Paris; 28% +/-8% for Milan region; 54% +/-16% for Madrid; not significantly observed for Athens), as compared to the same periods in 2019



Space-based Earth observation will provide amazing amount of complex, informative data : How to extract and use comprehensively this increasing information ?

- Operational Models and systems have strong limitation to exploit « extreme » data, i.e., too far from the model
- Research face to the necessity to focus their analyses of the underlined information and science



XCO2 IFS model simulation
provided by ECMWF
(from H2020 ECMWF CHE project)

PHIDIAS will provide new tools and approaches to deal with the measurements and the information, allowing better and more efficient use of the data, and pave the ways for finding new paradigms

Thank-you

Pascal Prunet, SPASCIA

Pascal.prunet@spascia.fr



www.phidias-hpc.eu

[@PhidiasHpc](https://twitter.com/PhidiasHpc)

phidias-contact@cines.fr



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