Smoothing of incomplete air pollution regions of interest from satellite observations

Master internship

General information

- Keywords : image analysis, segmentation, air pollution, ozone, satellite imaging
- Duration : 6 months (standard stipend). To start between February and April 2021.
- Institutes : Université de Paris, Laboratoire d'Informatique Paris Descartes (LIPADE), et CNRS / Université de Paris / Université Paris-Est Créteil, Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA)
- Location : 45 rue des Saints-Pères, 75006 Paris (LIPADE)
- Supervision : Laurent Wendling, Camille Kurtz, Nicole Vincent (first.lastname@u-paris.fr), Gaëlle Dufour (gaelle.dufour@lisa.ipsl.fr)
- Application : Please send a cover letter and a CV to Laurent Wendling. The position is opened until filled.

Proposed topic

Motivation

Environmental questions such as atmospheric pollution and climate change are key issues for our modern society to live in a more sustainable world. Addressing these issues requires large monitoring capabilities to quantify the evolution of the atmospheric composition and identify the chemical and dynamical processes which govern its evolution. Research in this field is to provide predictions and spatial descriptions of the various pollutants from the urban to the continental and the global scales. For these purposes, in situ observations and numerical modeling were traditionally set-up. More recently, improvements of satellite performances make satellite observations a powerful complementary tool for monitoring air pollutants. Their unprecedented spatial and temporal coverage allows one to probe the entire globe up to twice daily for more than a decade. This results in about one million measurements per day, represented as images. The challenge is to analyze all these data in an objective way to identify pollution events, track pollution plumes and their evolution over time, and identify the anthropogenic or natural origin of these plumes. The LISA lab is one the world leading groups in satellite remote sensing of tropospheric composition (first 15th kilometers of the atmosphere), develops several satellite retrieval algorithms to determine ozone and aerosols atmospheric distributions from satellite observations and now has over a decade of satellite images covering urbanized regions (China, Europe). In parallel, the LIPADE lab has a strong experience in the design of algorithms dedicated to the analysis of satellite image time series thanks to image analysis and AI paradigms. Our motivation in this intership subject is to be able to take advantage of such approaches to the experimental needs of LISA to be able to automate an atmospheric data processing chain, in order to make it faster, more objective and easily reproducible at a larger scale to deal with huge volumes of data.

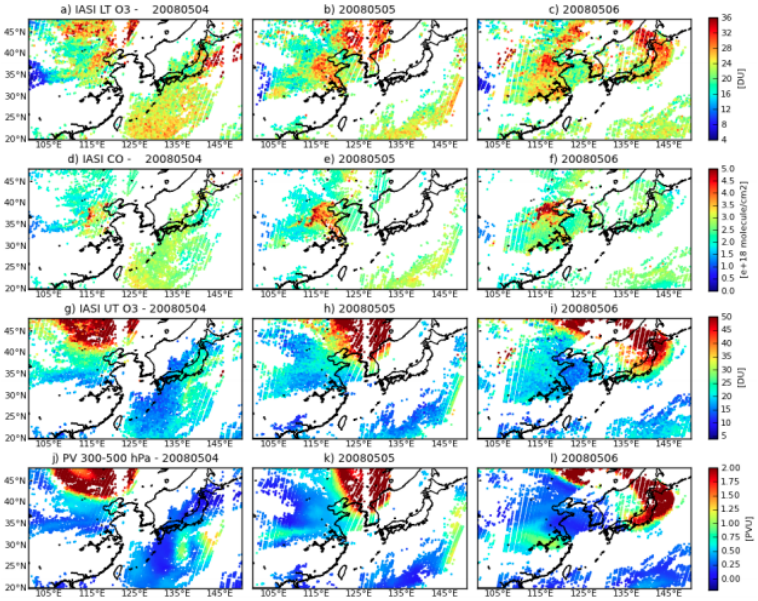

Figure 1 – Panels (a–c) : lower-tropospheric ozone columns (surface to 6 km a.s.l.) retrieved from IASI from 4 to 6 May 2008 ; panels (d–f) : total CO columns retrieved from IASI ; panels (g–i) : upper-tropospheric ozone columns (6 to 12 km a.s.l.) retrieved from IASI ; panels (j–l) : potential vorticity (PV) from ERA5 Interim reanalysis averaged between 300 and 500 hPa (images from [DUF15])

Background and state of the art

Satellite missions dedicated to air pollution and air quality monitoring have been booming since the 2000s with the development of satellite instruments able to detect and quantify concentrations of the main gaseous pollutants (nitrogen oxides, ozone, carbon monoxide,. . .). The LISA lab uses the radiances measured by IASI (Infrared Atmospheric Sounding Interferometer) onboard the European meteorological mission, Metop-A, to retrieve ozone distribution. One of the main challenges of ozone remote sensing is to infer ozone concentrations from the lower atmosphere (close to the surface). The ozone retrieval algorithm developed at LISA [ERE08] succeeds to separate the contribution from the lower (surface-6km) and upper troposphere (6-12km). As shown in [DUF15] for case study analysis over East Asia, this capability helps in the identification of the natural or anthropogenic origin of the ozone plumes (see Figure 1). Up to now, most satellite data analyses are done for a limited number of case studies where pollution events have been identified manually [DUF15] or are conducted to study the seasonal or interannual variability [DOC14] and trend of ozone using spatially and temporally averaged data [DUF18].

Proposed work and implementation

Contributions of the work to the state-of-the-art The particularity of the data is their incompletude and the imprecision of the measures, consequence of satellite trak offset or of clouds that can add noise to the data. The challenge is to deal efficiently with missing or incomplete image data. The traditional process (e.g. segmentation) of such image data would give some incomplete and irregular regions. The challenge is then to identify plumes from these naive regions of interest. The plumes have to be restored thanks to processes leveraging the missing and uncertain data. Fuzzy and morphological approaches can be referred to as well as spatial positioning of the naive regions considered as seeds using previous approaches developed by the project investigators [CLE17,CLE18]. Thanks to the amount of data, both tracking and visualization over time of the plumes can be achieved. This step would involve some previous works on movement studies in the Lipade inspired

from [ROT04]. Actually, no exogen data are included in the building of plumes, but it could be interesting to take them into account in order to label more efficiently the different plumes that are found.

Considered data We will consider satellite observations from IASI (Infrared Atmospheric Sounding Interferometer) on board the MetOp-A satellite to evaluate the daily variations of lower-tropospheric ozone over east Asia. Twelve full years of data (2008-2019) will be available for the project. The IASI instruments are nadir-viewing Fourier transform spectrometers that fly on board the EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) Metop satellites. In the framework of the project, we will focus on the first IASI instrument, which provides the longer time series. The field of view of the instruments is composed of a 2×2 matrix of pixels with a diameter at nadir of 12 km each, resulting in about 1300000 measurements per day.

Program of the internship The intern will start by preparing the data (images, metadata) and by choosing precisely the study area, in connection with the thematic needs of the laboratory. After the naive regions of interest are detected some merging approaches will be compared, including different criteria. The interest of incorporating some previous results in the previous days will be studied. The last step will be to evaluate quantitatively and qualitatively (from visual inspection by the LISA) the quality of the detection and tracking.

Desired background

We are looking for a student in Master 2 or final year of MSc, or engineering school in computer science. The ideal candidate would have knowledge in image processing, computer vision, machine learning and Python / C++ programming and an interest in handling large amount of data, and satellite imaging.

References

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ERE08 Eremenko, M., Dufour, G., Foret, G., Keim, C., Orphal, J., Beekmann, M., Bergametti, G., and Flaud, J.-M. (2008), Tropospheric ozone distributions over Europe during the heat wave in July 2007 observed from infrared nadir spectra recorded by IASI, Geophys. Res. Lett., 35, L18805

ROT04 Carsten Rother, Vladimir Kolmogorov, Andrew Blake : "GrabCut" : interactive foreground extraction using iterated graph cuts. ACM Trans. Graph. 23(3) : 309-314 (2004)

CLE18 Michaël Clément, Camille Kurtz, Laurent Wendling : Learning spatial relations and shapes for structural object description and scene recognition. Pattern Recognit. 84 : 197-210 (2018)

CLE17 Michaël Clément, Adrien Poulenard, Camille Kurtz, Laurent Wendling : Directional Enlacement Histograms for the Description of Complex Spatial Configurations between Objects. IEEE Trans. Pattern Anal. Mach. Intell. 39(12) : 2366-2380 (2017)