FAST RADIATIVE TRANSFER MODELS FOR THE DETECTION AND QUANTIFICATION OF GASES IN THE ATMOSPHERE USING HYPERSPECTRAL IMAGING

Topic# V-13 [Atmospheric Science]

Supervisor: Dr Frederic ANDRE, CNRS Researcher (French National Center for Scientific Research).
Co-supervisor: Dr Laurence CROIZE, ONERA Researcher (French Office for Aerospace Research).

PhD location: INSA de Lyon, FRANCE.

Keywords: hyperspectral images, satellite data, gaseous atmospheres, radiative transfer.

CONTEXT

In recent years, hyperspectral imagers have encountered a growing interest from various communities (geosciences, characterization of urban areas, atmosphere, defense, etc.). Compared to a traditional imaging device, spectro-imagery is an alternative efficient method that combines imagery and spectroscopy. Consequently, the output of an hyperspectral imager is not a 2D picture but a so-called *hypercube* (each pixel contains a spectral information, i.e. a spectrum that provides details on the emitting or reflecting properties of the object seen by the camera). Thus, a larger amount of information can be obtained by this technique than by many other existing methods. The drawback is the very large amount of data that are produced by such devices, which requires the development of specific tools to improve our capability to process the data at reasonable time costs.

That means that in order to infer data (gas temperature and composition, emissivity of surfaces i.e. buildings, landscapes, sea, etc.) from *hypercubes*, fast and accurate radiative transfer models are required. The aim of this PhD work is to contribute to the building and assessment of fast forward and inverse models for the detection and quantification of gases in atmospheric studies (analysis of spectra at medium resolution, i.e. of the order of a few tenth cm^{-1}, similar to those acquired by satellites). Approximate methods recently developed at CETHIL for the radiative characterization of cloudy atmospheres (projects supported by the National Program for Space Sounding, 2015-2018) will be used for this purpose.

RESEARCH PROGRAM

The first year of the PhD work will consists in: 1/ building reference high resolution spectra using the Line by Line Radiative Transfer Model LBLRTM, 2/ building approximate models for the radiative properties of gases based on the reference data, 3/ comparing radiative images calculated with the reference and approximate models. A limb geometry will be considered in this work.

The second year of the PhD work will be dedicated to the calculation of Jacobians (derivatives of the spectra with respect to the local properties encountered along the ray paths) by the reference and approximate methods. Detailed comparisons between the two techniques are the key results expected at the end of the second year.

The third year will be focused on applications of the tools developed during the first two years for the inversion of hyperspectral images. In a first step, the reference model will be used to simulate measured images. Then, in a second step, application of the tools to real satellite data coming from atmospheric sounding missions using a limb line of sight will be considered (typically MIPAS or ACE-FTS).

3 to 6 months during the total duration of the project will be dedicated to communication activities (for writing journal and conference papers, PhD manuscript).

BACKGROUND REQUIRED FROM THE APPLICANT

No specific background is required, as the student retained for the PhD work will follow classes on radiative transfer and gas radiation modeling (physics and approximate models) at the early beginning of his PhD work. However, a taste for statistical modeling (many tools used during the project will require basic knowledge in statistics) and for the development of numerical methods (in Fortran) is preferable.

A FEW WORDS ON THE SUPERVISORS

Dr. Frederic ANDRE obtained his Ph.D. from Ecole CENTRALE Paris in 2002. He joined CNRS and CETHIL (Center for Energetics and Thermal Sciences in Lyon, where the PhD student will be located) in 2004. He authored and co-authored more than 60 journal and conference papers. His main research activity is dedicated to radiative transfer studies in gaseous environments, including high (fire safety, heat transfer in engines and furnaces) and low (atmosphere, heat transfer in building) temperature applications.

Dr. Laurence CROIZE is graduated from École Normale Supérieure of Paris (Ulm). She obtained a Ph.D. degree in molecular spectroscopy in 2008. She authored and co-authored more than fifteen journal and conference papers. Her work includes research on spectroscopic techniques and their application to atmospheric sciences (from the model to the instrument), development of a rapid radiative transfer method based on Wide Band correlated-*k* method for MATISSE code (Advanced Earth Modeling for Imaging and the Simulation of the Scenes and their Environment), and preparation of atmospheric missions (spatial or on board stratospheric balloon) in close collaboration with the laboratories of atmospheric sciences.