A Passive Scanning Infrared Remote Sensing System for Identification, Quantification, and Visualization of Hazardous Clouds

Introduction
In the case of chemical accidents, terrorism, or war, hazardous compounds are often released into the atmosphere. In order to take appropriate measures to protect workers, residents, emergency response personnel at the site of the release, and the environment, information about the released compounds is required immediately. Passive remote sensing by infrared spectrometry allows detection and identification of hazardous clouds from a distance. For a complete assessment of the situation, information about the position and the size of the cloud is essential.

Passive Infrared Remote Sensing

The system is comprised of an interferometer with an azimuth-elevation-scanning system (Bruker RAPID), a video system with a DSP, and a personal computer. The control and analysis program (PC) displays a video image of the scene as a background image (Fig. 2). The operator may specify the field of regard using the mouse. The spectra are analyzed by a real-time identification algorithm that does not require background spectra for the analysis. The results are visualized by a video image, overlaid by false color images. For each compound of a spectral library, various images representing different results of the algorithm are produced. At a spectral resolution of 3 cm\(^{-1}\) up to 32 spectra per second are recorded, analyzed and visualized.

Identification

The first step of the identification is the calculation of the brightness temperature spectrum. This spectrum is analyzed sequentially for all target compounds that are stored in a spectral library. The spectrum is approximated by a linear combination of spectra which are contained in a reference matrix. Each matrix contains spectral data of one target compound, atmospheric gases, and the signatures of potential interferents. Moreover, it contains functions for the approximation of the baseline [1].

Quantification by Nonlinear Modeling

The radiance difference caused by the cloud is a function of the column density and the - unknown - difference between the temperature of the cloud and the brightness temperature of the background. However, the exponential dependence of the transmittance on the column density allows quantification by nonlinear modeling. In order to model the measured spectrum, a radiative transfer model and a model describing instrumental effects are required. The quantification is performed by approximation of the measured spectrum \(L_{\text{meas}}\) with a spectrum calculated using a model, \(L_{\text{model}}\) [2]:

\[
\sum_{i=1}^{N} \left( \frac{T_{\text{meas}}(\sigma_{i}) - T_{\text{model}}(\sigma_{i})}{T_{\text{model}}(\sigma_{i})} \right)^2 \rightarrow \min
\]

The instrumental line shape \(A^{\sigma_{i}}\) around \(\sigma_{i}\) is approximated by

\[
A^{\sigma_{i}}(\sigma) = A_{\text{f FTIR}}(\sigma) \ast A_{\text{inh}}(\sigma, \sigma_{i})
\]

where \(A_{\text{f FTIR}}\) is the Fourier transform of the apodization function and \(A_{\text{inh}}\) is a function describing the effect of broadening and the frequency shift caused by the finite étendue and aberrations. \(A_{\text{inh}}\) is numerically modeled by functions depending on a small number of parameters. Moreover, methods for the calculation of the best-fit parameters of \(A_{\text{inh}}\) have been developed.

Applications

Detection from Long Distances

Release of Sulfur Hexafluoride

Industrial Emissions

Airborne Pipeline Surveillance

Measurement of Aircraft Exhaust Gas Cooperation with IMK-IFU

Remote Sensing of Volcanic Gases Cooperation with INGV

Tomographic Mapping

References
