A new radiometer for continuous measurements of ozone and chlorine monoxide in the Canadian Arctic

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Introduction
Chlorine monoxide (ClO) is involved in all of the reaction sequences in which chlorine radicals, originally released from chlorofluorocarbons (CFCs), catalytically destroy ozone in the stratosphere. Accurate, long-term measurements of ozone (O₃) and ClO are needed in order to quantitatively understand the relationship between chlorine containing species and ozone loss rates in the Arctic.

Because of its low concentrations in the atmosphere, it is a challenging task to measure ClO from the ground. A new ground-based radiometer employing a sensitive, cooled superconducting detector is being developed at the University of Toronto for this purpose. The instrument will measure the intensity of radiation emitted from the rotational transitions of molecules in the atmosphere and can be used day and night for continuous observation. The radiometer will be housed at the Polar Environment Atmospheric Research Laboratory in Eureka, Nunavut (80.05° N, 86.42° W).

Observable species
The radiometer will operate in the frequency range of 265 – 280 GHz (approximately 1 mm wavelength) and observe a number of species related to Arctic ozone chemistry: ozone (O₃), chlorine monoxide (ClO), nitric acid (HNO₃), and nitrous oxide (N₂O).

![Figure 1: Spectral lines of the observable trace gases. The spectral lines for different gases sit on top of the water vapour absorption bands.](image)

Simulated Performance
“True” atmospheric states are created by allowing the a priori concentration profiles for each species to vary randomly within its climatological error covariance (Figure 5). An optimal estimation technique [5] is then used for the retrieval of the true state of each species, which is performed using the retrieval package, Qpack [6].

![Figure 5 – left: A simulated O₃ retrieval. The retrieval performs well but is unable to capture small scale variations in the true atmospheric profile.](image)

Instrument Design
The signal from the atmosphere is coupled to the detector with a series of flat and conic section mirrors. The quasioptical system is modeled using the physical optics software, GRASP (Figure 3).

After the first down-conversion, the signal is amplified, filtered, and down-converted a second time to ~ 2 GHz. With some further processing the signal is analysed by a Fast Fourier Transform (FFT) spectrometer to obtain the atmospheric spectrum.

As the radiometer will measure absolute intensity, it must be calibrated. Calibration loads are at ambient temperature and at 77 K. To remove instrumental nonlinearities from measurements of the weaker lines (ClO & HNO₃) the signals will be compared with a reference beam. An internal reference beam is created by blending together the signals from each calibration load using a wire grid polariser [4].

Mesospheric Wind Measurements
Wind speeds can be determined by measuring O₃ in two different viewing directions and comparing the Doppler-shifted line centers of the two mesospheric signals (simulated observations). The centre of gravity of the two mesospheric signals (simulated observations) is then used for the retrieval of the “true” atmospheric states. These are then used for the retrieval of the concentration profiles for each species, based on a measurement response of 80%.

![Figure 7 – top: A cut-off point can be used to isolate the mesospheric contribution to the O₃ spectral line. Bottom: Wind speeds can be determined by measuring O₃ spectra in opposite viewing directions and comparing the Doppler-shifted line centers of the two mesospheric signals.](image)

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References