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CLEAR-SKY RADIANCE MEASUREMENTS FROM THE FAR-IR TAFTS INSTRUMENT DURING EMERALD 2001

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1. INTRODUCTION

The influence of atmospheric humidity and clouds on the Earth's climate system is one of the major uncertainties in our present understanding of how the climate system works. Recent work has explained in detail how the infrared cooling to space of the Earth's surface and cloud-free atmosphere occurs, as a function of altitude and of spectral frequency. Clough et al, 1992, showed that a significant contribution to the outgoing longwave radiation (OLR) originated from the upper troposphere in the far IR between $100cm^{-1}$ and $500cm^{-1}$. Further theoretical work by Sinha and Harries (1997), have looked into the proportion of the OLR that can be attributed to the pure rotation band, concluding that 30-70% of the OLR originates from this band, depending on latitude.

The spectrally resolved heating rate is key to our understanding of heat loss from the atmosphere and is defined as:

$$\frac{dT_v}{dt} = \frac{g}{c_p}\frac{\Delta Fn_v}{\Delta p} \qquad (1)$$

where g is the acceleration due to gravity, c_p is the specific heat capacity at constant pressure, p and ΔFn_v is the net flux divergence over the pressure interval Δp. Although practically, the net flux divergence is calculated by finite differencing of measurements at various levels l, in the atmosphere.

Figure 1 shows a heating rate diagram for the mid-latitude winter standard model calculated from modelled radiance spectra at 44 levels, and shows how, in the spectral domain, the peak of the cooling moves from $500cm^{-1}$ to $100cm^{-1}$ with increasing altitude. This pattern is intrinsically linked to the distribution of water vapour in the troposphere, and small changes to the water vapour amount has a large influence on the effective emitting temperature across the band.

Despite recent progress, a number of difficult problems remain for the clear sky case. Apart from the distribution of humidity in the troposphere and its consequences for the global greenhouse effect; the exact nature of continuum absorption at the low temperatures typical of the upper troposphere is also unknown.

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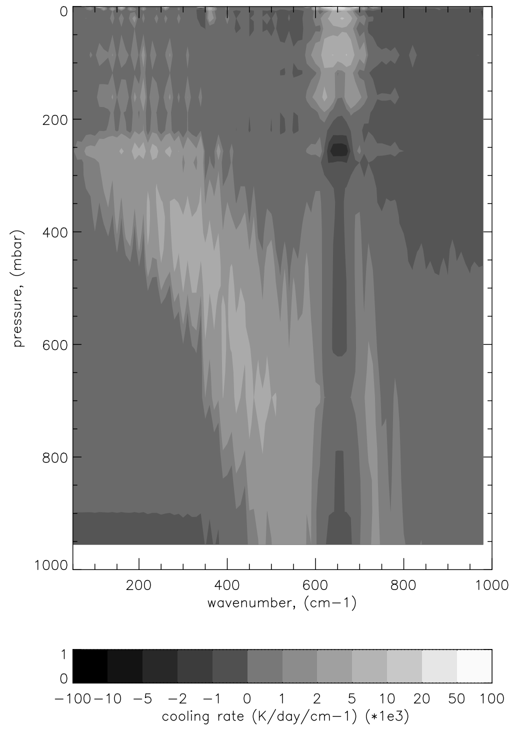

Figure 1. Mid-latitude winter standard atmosphere heating rate diagram.

This is because the current theory is an empirical one, relying on scant observations in the laboratory or the atmosphere to provide coefficients for the empirical description. High resolution aircraft data is necessary in the troposphere, to verify the models.

2. INSTRUMENT

To meet the need for high resolution measurements in the upper troposphere, Imperial College have built an aircraft instrument. The Tropospheric Airborne Fourier Transform Spectrometer, Canas et al, (1997), is a Martin-Puplett polarising FTS, and is the first to operate in this spectral range of interest with a spectral resolution of $0.12cm^{-1}$ over 80 - $750cm^{-1}$. This range is divided into two spectral bands, with a Si:Sb detector covering the shortwave between 320 - $750cm^{-1}$, and a Ge:Ga detector covering the longwave, 80 - $320cm^{-1}$ region; both detectors are helium cooled. TAFTS can view both in the nadir and the zenith as well as directly measure the net radiance, and with a radiance to flux conversion gives the net flux in equation (1).

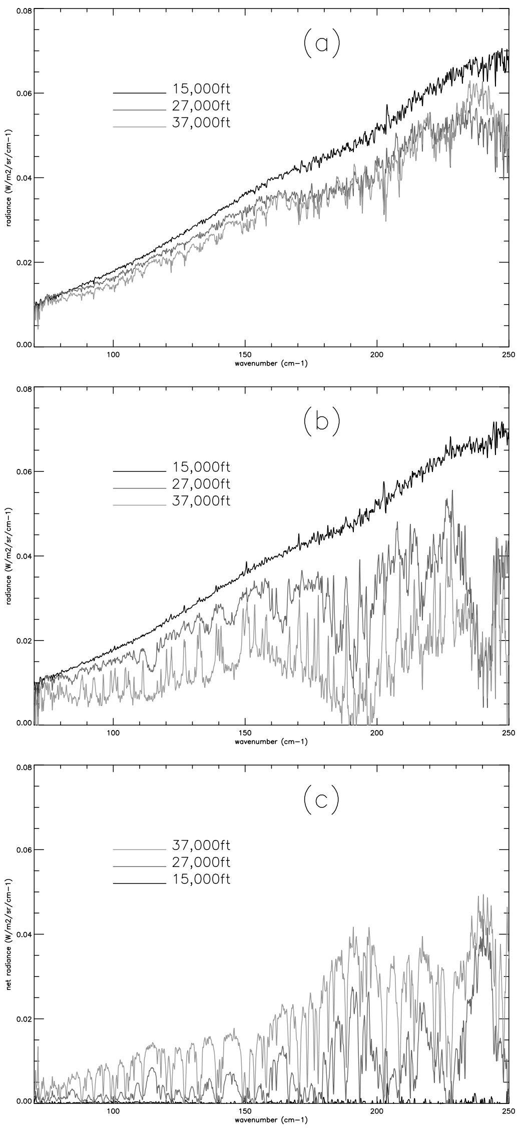

Figure 2. (a) upwelling, (b) downwelling, and (c) net clear-sky radiance at 15,000, 27,000 and 37,000ft measured over South Australia on the EMERALD campaign, (where net = upwelling – downwelling.)

3. EMERALD CAMPAIGN

The EMERALD campaign was a collaboration of three UK universities, and a team from DLR, in Germany, and took place in September / October 2001. Its aim is to study the radiation and microphysical properties of cirrus cloud, and clear sky atmospheres using two aircraft operated by Airborne Research Australia, in Adelaide, Australia. For this campaign TAFTS was installed upon ARA's Egrett aircraft, a slow flying high altitude aircraft that can reach heights of 15km.

4. PRELIMINARY RESULTS

Figure 2 shows longwave channel spectra (2 spectra, 4 second integration time,) from a flight in October 2001. The up- and down-welling radiance plots, (a) and (b), show the marked difference in the way the two radiation fields change with altitude, with the resulting net radiances in (c). Over the span of the ascent several hundred spectra were taken giving net fluxes on approximately 20 levels between 15,000ft and 37,000ft.

At low level, the net flux is zero across the entire band, but with increasing altitude the net radiance increases differentially across the spectrum. At low to mid-level the high wavenumber (180-250cm^{-1}) signal increases rapidly, whereas it is not until the mid to high-level the low wavenumber (50-150cm^{-1}) net radiance reaches the stratospheric value. The spikes seen most predominantly in the downwelling spectra are staurated water vapour emission lines due to the short path of warm air within the instrument pointing box, but cancel in the net flux calculation.

The shortwave channel data is still being processed, but is of similar quality to the longwave channel.

5. CONCLUSIONS

These results even though in a preliminary state, highlight the sensitivity of the far infra-red net radiance to tropospheric humidity distribution and are the first field measurements of the entire troposphere able to calculate the heating rate. A comparison of these results to cloudy flights also taken at EMERALD will also investigate the cirrus cloud signal in the far IR.

6. ACKNOWLEDGEMENTS

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