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Winter Anomaly – Trace Constituents Sounding Rocket Campaign

A High Resolution Photometer for Observing Daytime Lithium Releases

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Abstract. Differential photometer instruments which have been used to observe rocket-borne lithium trails in daytime have a limited resolution (about 0°.5 1° arc) with which it is difficult to observe trails at the lowest altitudes (80–95 km) and to make observations of turbulence and diffusion within the trails at altitudes up to about 110 km. A novel instrument which was built for, and used during, the Winter Anomaly project is described in this paper; it has a 0°.1 arc resolution, retaining the sensitivity of the conventional differential photometers. The instrument is based on a piezoelectrically-scanned Fabry-Perot interferometer of 0.05 nm spectral resolution.

Key words: Daytime neutral winds, thermosphere – Lithium trails – New high resolution photometer.

Introduction

The anticipated role of neutral wind measurements in the mesosphere and lower thermosphere in describing the atmospheric disturbances associated with Winter Anomaly conditions has been described in an accompanying paper (Rees et al., 1977). Reliable synoptic wind measurements up to about 90 km altitude were made throughout the Winter Anomaly project using chaff releases from Petrel rockets. These measurements were supplemented on the salvo days by lithium trail releases which, as described in Rees et al. 1977, provided reliable daytime measurements above 95 or 100 km. The height interval between 90 and 95–100 km was expected to be quite crucial to the completeness of the Winter Anomaly investigation, but it poses many difficult experimental problems. For the chaff release technique, due to low atmospheric density, the cloud falls very rapidly, and may thus not follow in detail the fluctuations of the wind field. On the other hand, for the lithium trail technique, the sensitivity and angular resolution of the conventional photometers, which are used to track the daytime trails, is adequate to properly detect and resolve the trail below about 95 km. In particular, these photometers cannot provide any significant information on the turbulent diffusion of low altitude trails below the 'turbopause' at about 105 km. Since an enhancement or reduction of the eddy or turbulent diffusion coefficient would significantly modify the rate of vertical transport of minor constituents into and out of the atmospheric region where Winter Anomaly effects are observed, and since a useful overlap of the altitude ranges of the chaff release and lithium trail techniques would improve the significance of the measurement of atmospheric dynamics and also allow some redundancy of measurement, it was decided to investigate the possibilities of extending the tracking of the daytime lithium trails to the lowest possible altitude.

Of the various instruments which have been used to observe daytime lithium releases (Best, 1970; Bedinger, 1970; Rees et al., 1972; Bedinger and Mills, 1977), only the airborne photographic technique of Bedinger and Mills 1977, with its accompanying problem of a requirement for a high flying jet aircraft (12 km +), can provide adequate spatial resolution to see small-scale structures (turbulence) within lithium trails up to 110 km (the conventional 'turbo-pause'), or actually to detect trails at the lowest levels, 83–90 km. The difficulties are shown diagrammatically in Figure 1, where the nominal trail expansion as a function of time after release is shown for various altitudes for molecular diffusion alone. The enhancement of trail expansion due to various rates of turbulent diffusion ($k = 100$, 200, 500 $m^2 s^{-1}$) is also shown. At 90 km, the lithium released decays rather rapidly so that, although after about 100 s the trail radius would exceed the sensitivity limit of the standard differential photometers, there may be insufficient metal vapour remaining for the trail to be visible.

A novel high resolution photometer was designed to attempt to overcome some of the shortcomings of spatial resolution, to attempt to push observations of the lithium trails to the lowest possible altitudes and to look for small-scale structures and turbulence within the trails. This instrument was utilized for the first time in the Winter Anomaly project from the Mazagon station (Rees et al., 1977) to supplement the observations made of three lithium trail releases by conventional dual-channel differential photometers.

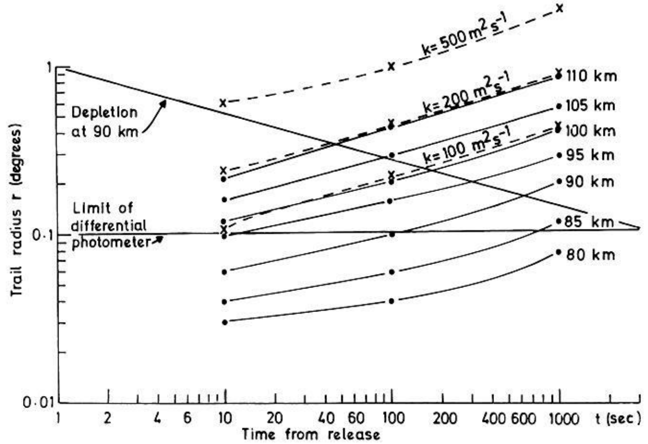

Fig. 1. Trail radius (degrees) as a function of time from release

Instrument Design Concept

The major design driving factors of a photometer for observing rocket-borne chemical trails in daytime are:

1. to obtain the highest possible spectral resolution to reduce the level of transmitted daytime sky brightness,
2. to obtain the highest possible spatial resolution to resolve the chemical trails and
3. to obtain the highest possible throughput with respect to emission from the lithium trail.

In a conventional differential photometer the instrument transmission can be written as:

$$F_S = \frac{1}{4\pi} \cdot Q \cdot \Omega \cdot A \left[(R \cdot k_1 \cdot k_2) t_1 \cdot t_2 + \int_0^\infty S(\lambda) \cdot t_S(\lambda) \cdot t_2 \cdot \mathrm{d}\lambda \right] \tag{1}$$

where F_S = the detected flux (photons s^{-1})
Q = the quantum efficiency of the detector
Ω = the solid angle of the instrument
A = the usable area of the interference filter in general
R = the surface brightness of the chemical trail (optically thick)
k_1 = the proportion of the field of view filled by a trail or cloud
k_2 = the optical thickness of the trail
t_1 = the sky transmission at the resonance wavelength
t_2 = the instrument transmission at the resonance wavelength
$S(\lambda)$ = the sky brightness as a function of wavelength
$t_S(\lambda)$ = the instrument transmission as a function of wavelength.

A typical solution for a differential photometer is shown in Table 1, using state of the art interference filters and 5 cm aperture optics. In the design of the differential photometer throughput has been sacrificed, to obtain a 0°.5 angular resolution, by a factor of about 25, without any corresponding gain in spectral rejection, to improve the contrast of the lithium trail against the daytime sky.

The novel design was intended to provide improved spatial resolution while compensating for the decreased field of view and thus throughput with improved spectral rejection, by using a 100 μ gap scanning Fabry-Perot etalon as the wavelength selective device. A 15 cm aperture Cassegrain telescope was used to improve the field of view matching to regain some of the throughput which would otherwise have been lost.

Table 1 shows the specification of the high resolution photometer for comparison.

While the two instruments perform similarly in terms of signal to noise ratio for an optically thick trail larger than 0°.5 in diameter, thus filling the field of view of both instruments, there is a major difference in the performance both with narrow trails and optically thin trails. For a 0°.1 trail diameter, and again a 0.005 s integration time, with an optically thick trail the signal to noise ratio of the high resolution photometer is about six times better than the differential photometer,

Table 1. Comparative performance of differential photometer and high resolution photometer

	Differential photometer		High resolution photometer
a. *Specification*			
Solid angle (Ω, sterad)	10^{-4}		3×10^{-5}
Area (cm^2)	20		26
$\int t_S(\lambda)\,d\lambda$ (nm)	0.4		0.025
Field of view (°)	0.5		0.1
Quantum efficiency		0.05	
Lithium trail brightness (Rayleighs)		0.5×10^6	
$k_1 = k_2$		1	
t_1		0.5	
t_2		0.8	
b. *Performance*			
Trail diameter (°)	2°	0°.1	0°.05
Optical density (τ)	1	1	0.2
Differential photometer:			
Signal due to lithium (cts.s^{-1})	1.5×10^6	3×10^5	3×10^4
Background due to sky (cts.s^{-1})	1.5×10^7	1.5×10^7	1.5×10^7
In 0.005 s:			
Signal	7×10^3	1.5×10^3	1.5×10^2
Background	7×10^4	7×10^4	7×10^4
Signal (S) to Noise (N) ratio[a]	20:1	5:1	0.5:1
High resolution photometer			
Signal due to lithium (cts.s^{-1})	6×10^5	6×10^5	6×10^4
Background due to sky (cts.s^{-1})	4×10^5	4×10^5	4×10^5
In 0.005 s:			
Signal	3×10^3	3×10^3	3×10^2
Background	2×10^3	2×10^3	2×10^3
Signal (S) to Noise (N) ratio[a]	30:1	30:1	6:1

[a] $N = (\text{Background} + \text{Signal})^{\frac{1}{2}}$

while the high resolution photometer has a × 10 advantage with a trail 0°.05 in diameter and an optical thickness $\tau = 0.2$.

From experience, it is rather difficult to observe clearly a trail where the signal to noise ratio for a 0.005 s sample falls below 5:1. Under 'perfect' skies (rarely obtained at sea level) the differential photometer thus fails to observe a cloud less than about 0°.1 or 0°.2 in diameter, which degrades to 0°.5 in the presence of even thin haze or traces of high cirrus cloud.

The high resolution photometer, however, is capable of resolving an optically thin trail ($\tau = 0.2$) 0°.05 in diameter, or an optically thick trail 0°.01 in diameter.

Referring to Figure 1, it can be seen that, allowing for metal depletion, the normal differential photometer will never see a trail below about 90 km except under 'perfect' conditions, while the high resolution photometer is capable of resolving trails down to about 80 km if an adequate vapour pressure of the free metal is stable in the atmosphere.

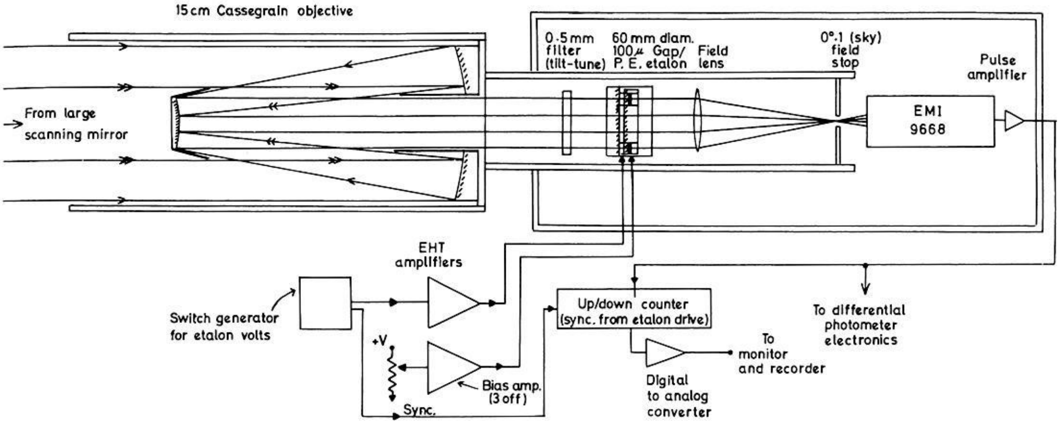

Fig. 2. Schematic design of high resolution photometer system

The realisation of a practical high resolution photometer is based on combining a scanning piezoelectric etalon of 60 mm aperture and 100 μ gap and finesse ~25 with a 1 nm band-pass filter tuned to the lithium 670.8 nm resonance line. A 15 cm Cassegrain telescope matches the etalon field of view for a 0.05 nm 'resolution', to obtain a 0°.1 field of view in the sky. The instrument is shown schematically in Figure 2. In practice, the piezoelectric etalon is switched between two wavelengths, one of which is the lithium resonance line. The photon count output is taken to feed an up/down counter which is synchronised with the etalon wavelength switching, and the output recorded on a digital magnetic cassette recorder, along with time code and azimuth and elevation information.

Instrument Performance

The high resolution photometer was used during all three of the B VI experiments on January 4 and 21, 1976, during the Winter Anomaly project, and appears to have performed very close to its specification. A section of the quick-look record obtained during the B VI/2 experiment is shown in Figure 3 (this is the direct data output taken from a rate meter in parallel with the input to the up/down counter). The departure from a rectangular wave-form is due to hysteresis of the piezoelectric crystals driving the etalon.

The approximate scale of this record section is shown underneath the data. For comparison, the same section of trail scanned by the differential photometer is also shown in the Figure. The altitudes of the 3 portions scanned (*A*, *B*, *C*) are approximately 115, 120 and 115 km respectively. During these experiments a relatively slow switching rate of the etalon was used, equivalent to a 0°.3 arc sample at the angular scanning rates which were used. The signal to noise ratio of the records indicates, however, that the switching rate could be increased by at least a

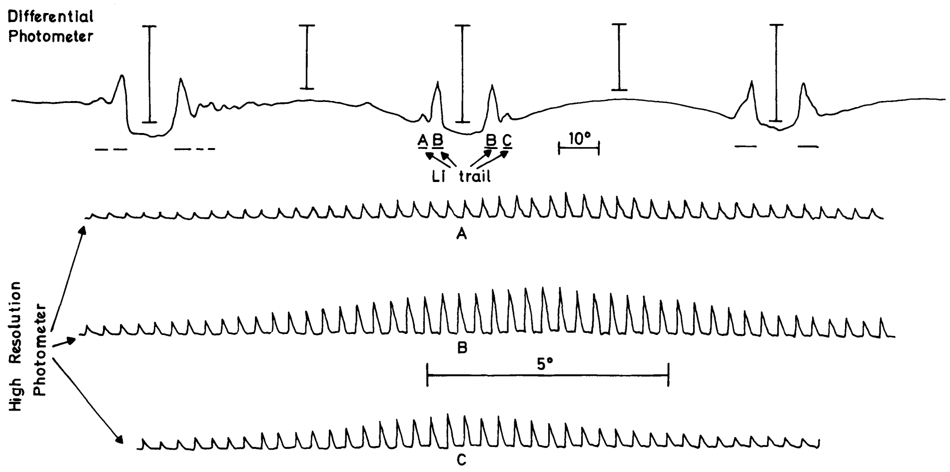

Fig. 3. Experimental data from high resolution photometer

factor of three to match the 0°.1 angular resolution of the optical system. For example, the lower portions of the trail (*A* and *C*), which are approximately 1°.5 in diameter, are barely resolved by the standard differential photometer, as can be deduced from the much lower amplitude of signals A and C relative to B (which is nearly 3° in diameter) in the differential photometer record compared with the relative amplitudes in the high resolution photometer record.

Conclusion

A high resolution photometer, built for, and used during, the Winter Anomaly project appears to be capable of observing daytime lithium trails at altitudes below about 85 km, and of obtaining useful measurements (turbulent eddies etc.) within trails and cloud releases under most conditions at altitudes greater than about 90 km.

Experimental data obtained during the B VI project is presently being analysed, in particular to examine the small-scale wind and turbulence features of the lowest altitude regions of each of the three lithium trail releases.

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References

Bedinger, J.F.: Detector for observation of high altitude winds during the daytime. Rev. Sci. Instr. **41**, 1234–1235, 1970

Bedinger, J.F., Mills, M.T.: Thermospheric wind measurements during project Aladdin, 1974. Space Res. XVII. (Presented at COSPAR, Philadelphia, 1976)

Best, G.T.: Daytime tracking of a high-altitude vapor trail. J. Atmospheric Sci. **27**, 979–980, 1970

Rees, D., Neal, M.P., Low, C.H., Hind, A.D., Burrows, K., Fitchew, R.S.: Neutral wind measurement during daytime in the thermosphere. Nature, London **240**, 32–33, 1972

Rees, D., Rounce, P., Killeen, T.L.: Winter anomaly – trace constituents sounding rocket campaign. Daytime neutral wind measurements in the mesosphere and lower thermosphere. J. Geophys. **44**, 47–56, 1977

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