

## Multi-channel ground-based and airborne infrared radiometers

G rard Brogniez, Michel Legrand,

Laboratoire d'Optique Atmosph rique USTL 59655 Villeneuve d'Ascq cedex, France

Bahaidin Damiri, Irina Behnert, Jean-Pierre Buis

CIMEL  lectronique, 172 rue de Charonne 75011 Paris, France

**Abstract.** Infrared radiometers CLIMAT (Conveyable Low-noise Infrared radiometer for Measurements of Atmosphere and ground surface Targets) CE312 (Ground version), and CE332 (Airborne version) built by CIMEL Electronique, are conceived to measure, from the ground level, or from an aircraft, radiances coming from surfaces, clouds, or atmosphere. The radiometers achieve simultaneous measurements in three narrow spectral bands in the atmospheric window between 8 and 14  $\mu\text{m}$  ( $700$  and  $1250\text{ cm}^{-1}$ ).

### Main characteristics and principles

- Digital radiometer with very good linearity.
- Very low noise, fast response, high stability over long term.
- Very weak change of sensitivity with the temperature, which permits its utilization in extreme thermal conditions, as at high altitudes.
- Only one sensitivity range whatever the incoming radiance.

The ground-based radiometer CE312 uses a thermopile situated into one cavity. A filter wheel allows the successive selection of the radiance incident into the thermopile in three narrow bands with FWHM =  $1\text{-}\mu\text{m}$ , centered at  $8.7\text{ }\mu\text{m}$ ,  $10.5\text{ }\mu\text{m}$ , and  $12.0\text{ }\mu\text{m}$ . In addition, a broad-band ( $8\text{-}13\text{ }\mu\text{m}$ ) measurement is also performed.

The airborne radiometer CE332 is composed of three cavities, i.e. one per channel, so that simultaneous measurement, particularly suitable for airborne measurements, can be performed. Each cavity has its own thermopile and optics.

Note that for each radiometer, the filters are interchangeable.

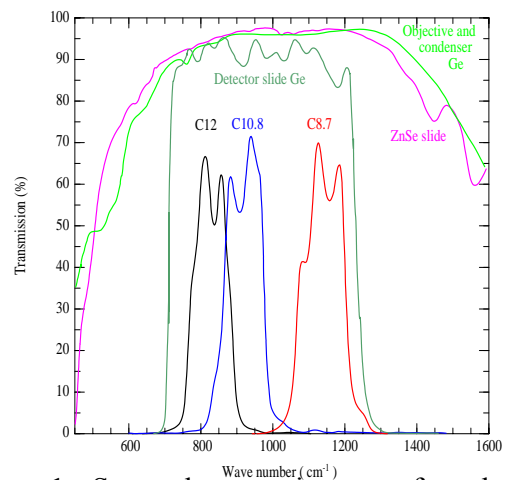
Both radiometers have Ge lenses with a non-reflective treatment. Dimensions and shapes of the objective (convex-plane lens), and of the condenser (meniscus lens), have been designed to minimize the geometrical aberrations. The condenser is located in the focal plane of the objective following the K hler design. Then, the optical field of view is well delimited, with a value of  $10^\circ$  for CE312, and  $3^\circ$  for CE332, at half maximum.

The main advantages of thermopiles (thermal detectors) are the ambient temperature of operation, and a high level of detectivity, independent of the wavelength.

Detectors are equipped with a germanium window (between 8 and  $14\text{ }\mu\text{m}$ ). Above  $15\text{ }\mu\text{m}$ , the radiation is blocked by a ZnSe window. Spectral transmittances of the objective  $F_L(\nu)$ , of the condenser  $F_C(\nu)$ , of the ZnSe filter  $F_Z(\nu)$ , of the detector window  $F_D(\nu)$ , and of the three narrow band-pass filters  $F_i(\nu)$  have been measured. They are presented on the Figure 1 for the airborne instrument.

The global transmittance of the optics is given, for each channel  $i$ , by the transmittance product of each element:

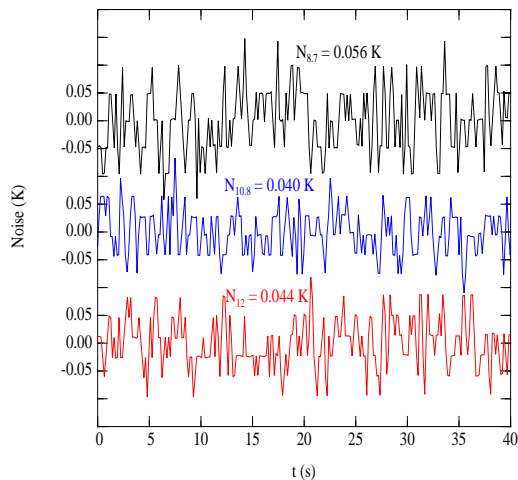
$$F_G^i(\nu) = F^i(\nu) \times F_L(\nu) \times F_C(\nu) \times F_Z(\nu) \times F_D(\nu).$$



**Figure 1.** Spectral transmittance of each optic element of the radiometer CE332.

The cavities are not thermostatically controlled but accurately monitored by a platinum probe with a temperature sensor. Each cavity is used as a reference of radiance (Legrand et al., 2000). A gilded concealable mirror with a high reflection coefficient (99.74%) over the spectral domain  $8\text{-}14\text{ }\mu\text{m}$  is located in front of the optical head. This mirror allows the radiance originating from the target (opened position) and from the thermopile cavity (closed position) to be compared. The airborne radiometer needs a pre-heating time of about 20 min (due to the thermal insulated cavities). The response time of the thermopile is 12 ms, and the acquisition frequency is 1s for the ground-based version, and 160 ms for the airborne

version. The noise  $N$  (expressed in term of standard deviation of brightness temperature for a cavity temperature  $T_C = 280$  K) is about 0.05 K in each channel (Figure 2).

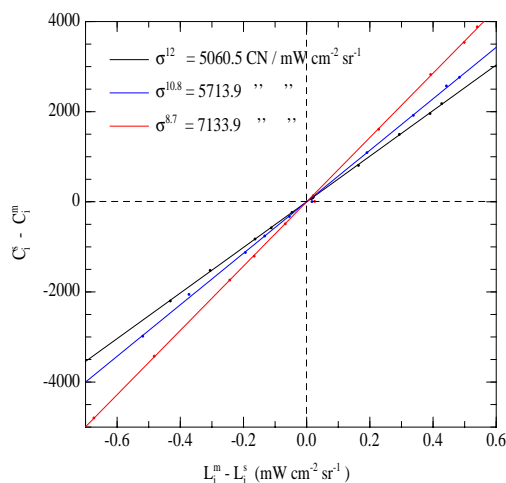


**Figure 2.** Noise of the radiometer in term of brightness temperature, on the three channels of the radiometer CE332.

The principle of the instrument is based on a differential method using the concealable mirror. The difference between the counts obtained with opened and closed positions of the mirror is linearly related with the corresponding radiances, as can be seen in Figure 3.

$C_s^i - C_m^i = \sigma^i (L_s^i - L_m^i)$ , where  $\sigma^i$  is the sensitivity of the radiometer for channel  $i$ .

Stability  $\frac{\Delta\sigma^i}{\sigma^i}$  of sensitivities is better than 1.5% per year, so that an internal blackbody is not useful.



**Figure 3.** Sensitivities of the three channels of the radiometer.

### Potential applications

The applications of these instruments are manifold. At the LOA they have been used for atmospheric research: cirrus cloud study – see French/Dirac airborne campaign (Brogniez et al, 2004), atmospheric dust (Pancrati, 2003). These instruments are also used in agronomy, geology, and for the determination of sea surface temperature using a split window method (Brogniez et al., 2003). They are also helpful for the determination of surface emissivities.

### References

- Legrand, M., C. Pietras, G. Brogniez, M. Haeffelin, N. Abuhassan, M. Sicard, A high-accuracy multiwavelength radiometer for in situ measurements in the thermal infrared. Part I: Characterisation of the instrument. *J. Atmos. Ocean. Technol.*, 17, 1203-1214, 2000.
- Brogniez, G., C. Pietras, M. Legrand, P. Dubuisson, M. Haeffelin, A high-accuracy multiwavelength radiometer for in situ measurements in the thermal infrared. Part II: Behavior in field experiments. *J. Atmos. Oceanic Technol.*, 20, 1023-1033, 2003.
- Pancrati, O., Télédétection de l'aérosol désertique depuis le sol par radiométrie infrarouge thermique multibande. *Thèse de l'Université des Sciences et Technologies de Lille*, 203 pp, 2003.
- Brogniez, G., F. Parol, L. Bécu, J. Pelon, O. Jourdan, J. F. Gayet, F. Auriol, C. Verwaerde, J. Y. Balois, B. Damiri, Determination of cirrus radiative parameters from combination between active and passive remote sensing measurements during FRENCH/DIRAC 2001. *Atmos. Res.*, 72, 425-452, 2004.