New High Resolution Observations of the Solar Diameter from Space and Ground with the Microsatellite Program PICARD

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Abstract. The PICARD microsatellite mission will provide 2 to 6 years simultaneous measurements of the solar diameter, differential rotation and solar constant to investigate the nature of their relations and variabilities. The 100 kg satellite has a 40 kg payload consisting of 3 instruments which will provide an absolute measure (better than 10 milliarcsec) of the diameter and the solar shape, a measure of total solar irradiance, and UV and visible flux in selected wavelength bands. Now in Phase B, PICARD is expected to be launched before mid-2003. The engineering model of the diameter telescope will be used on ground simultaneously with the satellite to investigate the atmospheric bias and state on the possible accuracy of the ground measurements carried up to now. We review the scientific goals linked to the diameter measurement, present the payload, and give a brief overview of the program aspects.

Key words. Solar diameter—solar shape—long-period oscillations—g-modes—solar influence on climate.

1. Introduction

Since solar energy is one of the major driving inputs for terrestrial climate and since some correlations between surface temperature changes and solar activity exists, it appears important to know on what time scale the solar irradiance and other fundamental solar parameters, like the diameter, vary in order to better understand and assess the origin and mechanisms of the terrestrial climate changes.

Global effects, such as diameter changes, large convective cells, the differential rotation of the Sun’s interior and the solar dynamo at the base of the convective zone, can probably produce variations in the total irradiance or, at least, correlate with these variations associated, during maximum, with the changing emission of bright faculae and the magnetic network. The aim of these correlations is twofold: on one side prediction and on the other explanation of the past history of climate, like the Maunder minimum period.

To establish long-term links and trends between solar variability and climate changes, it is necessary to achieve not only high precision but also absolute measurements, which the diameter measurements of PICARD aim at. Further, this high precision allows “instantaneous” monitoring of the diameter changes, i.e., with a proper orbit for the microsatellite, oscillations and, in particular, the gravity modes.
2. Scientific objectives

2.1 Why the diameter?

From 1666 to 1719, Jean Picard and his student Philippe de la Hire measured the solar diameter, observed the sunspots and determined the Sun rotation velocity. Fortunately, these measurements covered the Maunder minimum and some time after. The data were re-examined by Ribes et al. (1987) who, after removing the seasonal variation of the solar diameter, obtained the annual means at 1 AU. These values, averaged for the Maunder minimum period, show a significant difference of the order of 0.5 to 1 arcsec and after the Sun recovered a significant activity, corresponding to a larger Sun diameter during the Maunder minimum. As expected, few sunspots were observed. However, Picard’s data also showed a slow down of the Sun's rotation velocity at the equator and more sunspots in the southern hemisphere than in the north.

2.2 Diameter and earth's climate

The solar constant measurements performed in space by the radiometers since 1978 were modeled using the sunspots number and faculae. This allowed the reconstruction of the solar constant variation back to 1610 (Lean 1997). This showed that the solar constant experienced a significant decrease during the Maunder minimum. The temperature in the northern hemisphere has been also reconstructed for the same period. The cooling of this period is known as the Little Ice Age. The similarity of the temperature and solar constant variations strongly suggests the Maunder minimum to be the cause of the Little Ice Age. To assess this suggestion, climate models were run by Sadourny (1994) that showed the Maunder minimum as the possible cause of the Little Ice Age. Volcanic eruptions (major ones) also play a certain role, but their effects do not extend over more than a few years.

In a similar fashion, the modern data of solar diameter measurements and sunspots number, set together by Laclare et al. (1996), reveal an increase of the Sun's radius for a decrease of the solar constant. We propose to operate from space by measuring simultaneously both quantities from the same platform and in non-magnetic lines or continuia in order to establish experimentally without ambiguity the solar constant and diameter relationship. The importance of the measurements for climatology is straightforward, taking into account the Little Ice Age and the Maunder minimum events.

2.3 Prediction and precision

The total solar irradiance measurements made by radiometers from space over the last 20 years, is excellent in relative terms ($10^5$) but poor in absolute. The amplitude of the variation over the cycle (0.1%) is small and is about the same as the uncertainty on the absolute value from one instrument to the other. Prediction of climate change from such data is not straightforward and the adjustment of datasets of different origins is an art (cf. Fröhlich & Lean 1998). On the contrary, if the relation irradiance-