Summary: The Polarized Instrument for Long-wavelength Observation of the Taurus interstellar medium (PILOT) is a balloon-borne experiment aiming at measuring the polarized emission of thermal dust at a wavelength of 240 μm (1.2 mm). A first PILOT flight (flight1) of the experiment took place from Timmins, Ontario, Canada, in September 2015 and a second flight (flight2) took place from Alice Springs, Australia in April 2017. These flights are the first of the PILOT instrument and are a step towards the full flight response flat field and its time variations using the signal from the residual atmosphere and of our internal calibration source. The flight performances are found to be satisfactory and globally in line with expectations from ground calibrations. We conclude by assessing the expected in-flight sensitivity of the instrument in light of the above in-flight impacts (glitches) and of our internal calibration source. We use these time constants to deconvolve the data timelines and analyse the optical quality of the instrument as measured on planets.

The optics is composed of an off-axis paraboloid primary mirror (M1) of 0.83m diameter and an off-axis ellipsoid secondary mirror (M2). All optics following M1 is cooled at cryogenic temperature of 2 K. The telescope is followed by a re-imager and a polarimeter through a flat mirror (M3). Two lenses (L1 and L2) are used to re-image the telescope onto the detectors. A Lyot-stop is placed between the lenses in a pupil plane, which is conjugate of the primary mirror. A rotating Saphire Half-Wave Plate (HWP), is located next to the Lyot-stop, which introduces a phase delay between the two orthogonal components of the incident light. A polarization analyzer is placed at a 45° angle in front of the detectors, in order to transmit one polarization to the transmission (TRANS) focal plane of the instrument and the other polarization to the reflection (REFLEX) focal plane. Observations at at least two, different HWP angles allow us to reconstruct the Stokes parameters I, Q and U.

Flight1 of the PILOT experiment took place from the launch-base facility at the airport of Timmins, Ontario, Canada on September 21, 2015. Flight2 was conducted from the USA-operated launch base of Alice Springs, Australia on April 16, 2017. The launches were part of campaigns led by CNES and the local Space Agencies (CSA, NASA). In both cases the payloads were recovered safely at the end of the flight.

Detector time constants: We fit the progressive signal decay following an illumination by the ICS in order to derive the detector optical time constants. However, this decay time has a contribution due to the thermalization process, which we estimate by comparison with the time constant values obtained from the power spectrum analysis of glitches, which are produced by the interaction with high energy particles. We used glitches above 100 ADU (rate=2.24 giga/pixel). We derived a time constant for ICS of 10.2 ms (±4.6 ms) and a time constant for glitches of 17.5 ms (±7.5 ms). The map of the detector time constants derived are shown in Fig. 1.

Response calibration: We measure the spatial distribution of the detector response using the residual atmospheric emission. We measure the slope of the correlation between the bolometer signal and the local sky emission during the science elevation using 20°-variable elevation angles. Figure 3 shows the focal plane map of the mean response. The pattern is similar to that observed during ground test, where the focal planes were operated in front of an extended black-body. The accuracy of the response map is at the 1% level or better when using all observations. This confirms the advantage of using a scanning strategy with varying elevation as implemented in the flight 2.

We measure the time variations of the detector response using the ICS signal. Figure 4 shows the time variations of the array-averaged detector response to the ICS signal for array #6 during flight 2. The response in the variation of time are about 10% for all arrays. Step-like variations are clearly seen in both the TRANS and REFLEX arrays. These variations are mostly caused by variations of the background level on the detectors. Some are due to changes of the observation elevation, which changes the intensity of the residual atmospheric emission. Some are due to changes observed with different HWP angles, which, due to the polarization of the instrumental background (see Misawa et al. 2017), changes the detector background.

First results on the Galactic center: From our measured dust polarization angles, we infer a magnetic field orientation projected onto the plane of the sky (POD) that is remarkably ordered over the full extent of the Central Molecular Zone (CMZ). Figure 6 shows the angle with respect to the Galactic plane. Our results confirm previous claims that the field traced by dust polarization is oriented nearly orthogonally to the field traced by geodesic radio synchrotron emission in the Galactic center region. The observed field structure is globally compatible with the latest Planck polarization data at 353 GHz and 217 GHz. Under subtraction of the extended emission as our data, the mean field orientation that we obtain shows good agreement with the mean field orientation traced at high angular resolution by the JCMT within the 20 km/s and 50 km/s molecular clouds. This field orientation is related to the 100 pc twisted field structure within the CMZ. The low polarization fraction in the Galactic center region suggests that the region is probing an extended, turbulent, and possibly turbulent field orientation is unusual. This feature actually extends to the whole inner Galactic plane. We propose that it could be understood by the increased number of turbulent cells for the long times of sight towards the inner Galactic plane or to dust properties specific to the inner regions of the Galaxy. Assuming equipartition between magnetic pressure and ram pressure, we obtain magnetic field strength estimates of the order of 1 mG for several CMG molecular clouds.