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Comment on amt-2022-93

Anonymous Referee #1

Referee comment on "A fiber-optic distributed temperature sensor for continuous in situ profiling up to 2□km beneath constant-altitude scientific balloons" by J. Douglas Goetz et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-93-RC1, 2022

Review of preprint , A Fiber Optic Distributed Temperature Sensor for Continuous in situ

Profiling 2 km Beneath Constant-altitude Scientific Balloons‘,
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Summary:

This article presents a novel fiber-optic (FO) sensor and application for collecting spatially continuous temperature profiles from an untethered balloon. While the authors designed the system to collect samples at the interfacial layer between the upper troposphere and lower stratosphere (UTLS) across a maximum layer of 2 km, deployments across other atmospheric layers and height ranges are conceivable as long as the prerequisites for pressures and temperature ranges of the contained sensors and the balloon’s buoyancy are met. To my knowledge, it’s the first system of if its kind with an independent untethered (from a ground station) sampling, processing and storage unit contained in the balloon’s gondola unit and in this sense is unique and innovative. Since all electronics including the laser optical bench, loggers, and power supplies need to be carried as payload, some sampling limitations result regarding minimum averaging time (reported as 20 s) and spatial resolution along the fiber (reported as 3 m) in comparison to ground-based fiber-optic distributed sensing (FODS). The latter offer a minimum sampling at 1 Hz and 0.125m. The FLOATS’ sampling limitations pose some noteworthy restrictions on the scientific merit of the collected data, particularly when observations from the strongly instationary ascent and descent phases with great vertical velocities and sharp temperature changes are analyzed. However, given the unique, lightweight, retrievable design of the sensor being able to collect continuous observations over weeks and months, it is a fascinating addition to the family of Raman-scatter based FODS aerial applications. I have very few comments on the technical and data analytical aspects of the study.

However, there is one significant weakness: given the FLOATS' unique sampling capabilities and innovative design, I am somewhat puzzled why the authors present its proof-of-concept study using the Wyoming WY933 test flight, which suffered from three major shortcomings: first and foremost, the temperature reference sensor No. 4 contained in the end of fiber unit (EFU) malfunctioned during the float and descent stages preventing a meaningful post-flight calibration of raw Stokes/AntiStokes ratios into aerial temperatures for length along the fiber (LAF) bins past the rotary connector. While the authors found some work-around and provide some calibrated data, its quality is not representative of the sensor's true capabilities. Second, the fiber-optic cable was only 1200m long. Given the exponential decay of the signal to noise ratio of the Raman photons across the FO cable, assessing measurement uncertainty at the shorter 1200 m LAF distance compared to the full 2000m is different. Third, the deployment at float height (90 min) was too short to resolve the typical period length of gravity waves in the tropopause of several hours, as indicated by the authors. I believe that these shortcomings pose significant limitations on evaluating true system performance regarding accuracy of the retrieved temperature profiles, as well as resolving vertical structure of the UTLS which appears to be of great concern to the authors, as I understand. For me, a proof-of-concept introducing a novel sampling technique shall showcase a system's true capabilities so the reader can decide about its suitability for similar applications. The WY933 flight does not fulfill these requirements. The authors mention that other flights exist (ln 80, Strateole 2 campaign), so why not use those? It is ultimately up to the authors and the editor to decide whether they want to introduce FLOATS with a fizz, rather than a bang – I believe the latter would be in order.

I have a few minor comments in addition to the main criticism.

In summary, I recommend publication of the study on the novel FODS sampling system using a different, more meaningful dataset, if at all possible. Such an article would demonstrate the system's true capabilities and have significant technical and scientific merit.

Minor comments:

- Ln 51: The authors may not be aware of the tethered balloon deployment using FODS by Fritz et al. (2021) to sample the near-surface boundary layer thermal structure at high spatiotemporal during the morning transition. There are many parallels regarding technical (resolution, assumption of negligible curvature resulting in linear conversion of LAF into height above ground, etc) and scientific (changes in static stability, gravity waves, automated indemnification of layers of similar stability, etc) aspects, so I would like to bring it to their attention for completeness and comparison of uncertainties including those to ground-based remote sensing systems. Citation: Fritz, A.M., Lapo, K., Freundorfer, A., Linhardt, T., Thomas, C.K., 2021. Revealing the Morning Transition in the Mountain Boundary Layer Using Fiber-Optic Distributed Temperature Sensing. Res. Lett. 48, e2020GL092238. https://doi.org/https://doi.org/10.1029/2020GL092238

- Ln 80: As mentioned before, I believe the long-duration deployment during Strateole 2 would be much better suited to showcase FLOATS' capabilities.

- Ln 130: Can you give an uncertainty range for the constant temperature environment of the gondola? This may have important implications during long-duration flights characterized by changing thermal and light environments, and resulting changes in post-flight FODS calibration. Was the sensitivity of the calibration parameters to the temperature of the electronics evaluated in the laboratory?

- Ln 144f: Is there any reinforcement fiber (Kevlar,…) contained in the FO cable? What is the color and albedo of its outermost jacket?

- Ln 200ff: I noticed that the authors do not necessarily use the terminology commonly used in the aerial FODS literature (e.g. differential attenuation, single-ended, non-duplexed, etc). For ease of reading and comparison with existing studies, I recommend using this nomenclature (see e.g. Thomas, C.K., Selker, J.S., 2021. Optical fiber-based distributed sensing methods, in: Foken, T. (Ed.), Springer Handbook of Atmospheric Measurements. Springer Handbooks, Springer Nature Switzerland AG 2021, pp. 609–631. https://doi.org/10.1007/978-3-030-52171-4_20).

- Ln 245f: Step losses from FO cable breaks or optical connectors need to be treated entirely different from estimating the continuous differential attenuation during postfield FODS calibration. Since the optical junction at the rotary connector between the gondola FO cable (between Reference 1 and 2), and the actual ambient sampling FO cable is not held at a uniform temperature, I do not see the utility of the fitted three unknowns for the gondola cable for application to the ambient cable to assess the different (and cumulatively changing) effective differential attenuation of the optical path from the bench to the end of the FI cable at the EFU. The design must call for at least two separate known reference sections (Ref3 and Ref4) to assess the change in the differential attenuation. This is the main reason why WY933 is ill-posed. How does your calibration routine compare to established methods such as des Tombe, B., Schilperoort, B., Bakker, M., 2020. Estimation of Temperature and Associated Uncertainty from Fiber-Optic Raman-Spectrum Distributed Temperature Sensing. Sensors 20. https://doi.org/10.3390/s20082235?

- Ln 286: The shortwave radiation error for aerial FO deployments was discussed in detail by Sigmund, A., Pfister, L., Sayde, C., Thomas, C.K., 2017. Quantitative analysis of the radiation error for aerial coiled-fiber-optic distributed temperature sensing deployments using reinforcing fabric as support structure. Atmos. Meas. Tech. 10, 2149–2162. https://doi.org/10.5194/amt-10-2149-2017. I believe the models and equations contained in this manuscript could strengthen the discussion in this paper. I am particularly concerned about non-uniform shortwave exposure across the ambient FO cable. For future applications: could the simultaneous use of a twisted (or parallel) black and white FO cable offer insight and utility?

- Ln 313: I believe this is the most significant shortcoming for the presented dataset.

- Ln 380: I think to recall conflicting information about when Ref4 ceased to work properly: was it still operational during ascent (cp. Ln 396), or did it fail during the float?

- Ln 406: It's a tightly buffered FO cable, so mechanical strain inflicted during retraction and because of temperature changes is most likely. Was it reversable when FLOATS was on the ground?

- Ln 416ff, 434f: This section can be improved: the resulting effective vertical resolution of the FODS observations are a function of vertical velocity of the sampling unit, the FO cable's and optical bench response time, and the minimum averaging interval. Combining those will yield an effective resolution and uncertainty.

- Table 1: Given the uncertainty of the optical bench, the 2nd decimal place for FODS temperatures may not be significant? Please check and adjust if necessary.

- Figure 4: A profile of the temperature differences between the two sensors in relation to the height-dependent temperature gradient may make a meaningful addition to evaluate performance. Can you explain why your analysis focuses on ascent profiles, while the true strength of FLOATS lies with the float stage as spatially continuous, simultaneous profiles are collected? Is this for comparison reasons only?

- Ln 522: What metrics are the basis for this statement? Overall shape, or height of strong temperature changes, or…? As a boundary-layer meteorologist I may not be aware of what is most important for UTLS dynamics.

- Ln 613ff: See comment above, I recommend using a different dataset for this proof-of-concept study.

- Ln 663: Analyses of temperature spectra (from FFT, wavelet, MRD etc) between FLOATS and reference sensors in controlled conditions may make a nice addition to evaluating system performance, particularly when having ABL turbulence applications in mind.