



The 9th International Electronic Conference on Sensors and Applications

01-15 NOVEMBER 2022 | ONLINE

Air temperature measurement using CMOS-SOI-MEMS sensor dubbed Digital TMOS

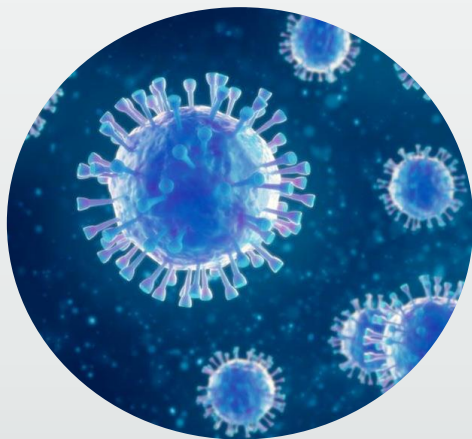


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Motivation

- **Air Temperature is an important meteorological parameter**
- **Usually observed using a radiation shield with ventilation**
- **In rural areas, such auxiliary equipment is not available**



**Human health &
Virus
propagation**



**Growth &
Reproduction of
plants**



hydrology



**Climate
change**

The Challenge

Thermometers cannot measure air temperature accurately

Measurements affected by environmental parameters:

- **Humidity**
- **Solar radiation**
- **Wind velocity and direction**
- **Rainfall**
- **Atmospheric pressure**

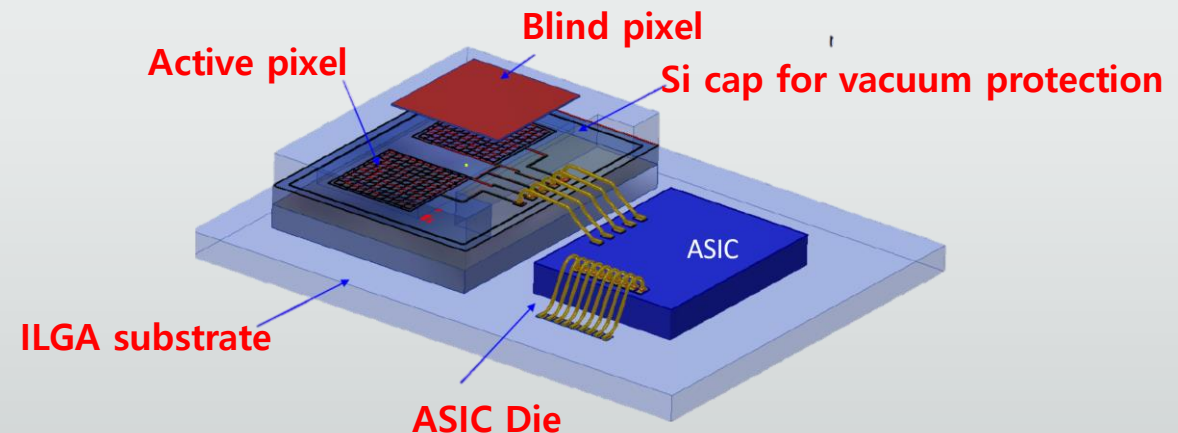
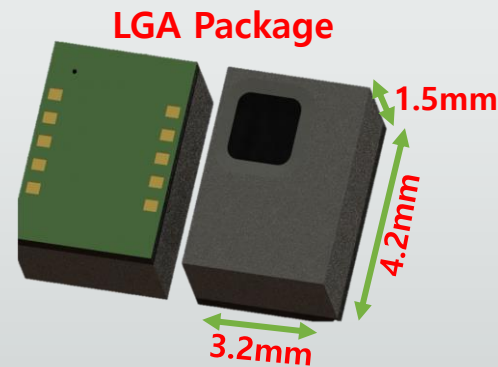
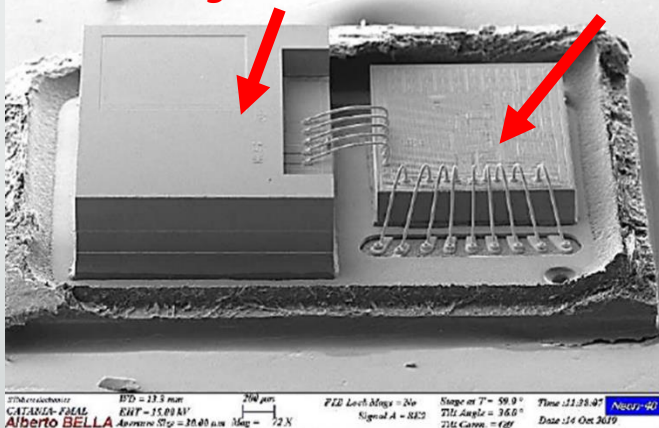
The Innovation of this study

- **The use of the Digital-TMOS manufactured by STM / system extended by TODOS- Technologies.com**
- **A narrow optical band pass filter ($4.26 \pm 0.09 \mu\text{m}$) corresponding to the CO₂ carbon dioxide absorption band**
- **measuring simultaneously the weather parameters**

The Innovation: The Digital-TMOS manufactured by STM

- Analog TMOS sensor integrated with an ASIC die where the analog signals are converted to digital signals and Digital Signal Processing
- **Integrated PTAT**- Proportional To Absolute Temperature Circuit
- organic LGA package compatible with Surface Mount Technology (SMT)
- integrated optical window and filter

SEM Image of Digital TMOS:
Packaged Sensor bonded to ASIC



TODOS TECHNOLOGIES Digital-TMOS Tailored to Air Temperature Measurements, inside a passive radiation shield (the BOX)

- The box system tailored to air temperature measurements contains two **Digital TMOS's units**, each covered with **narrow optical filter**, $4.26\mu\text{m}\pm 90\text{nm}$
- **Two units** are used to validate the measured results

2 Digital TMOS units with CO2 filters



Metal Tube used as field of view limiter



PCB

Air Temperature Box with the Digital-TMOS, Microcontroller and additional environmental sensors

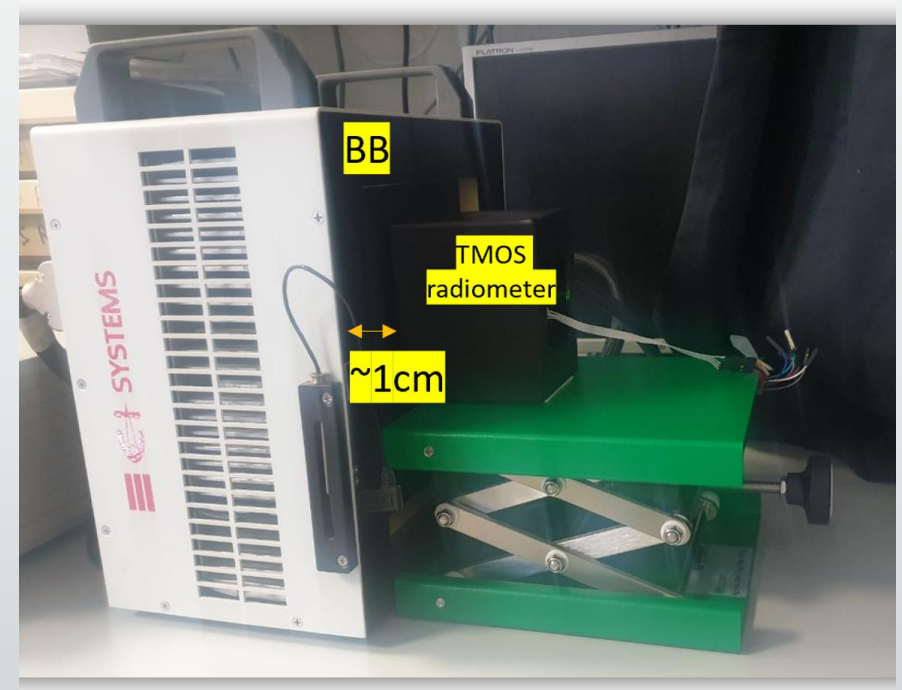
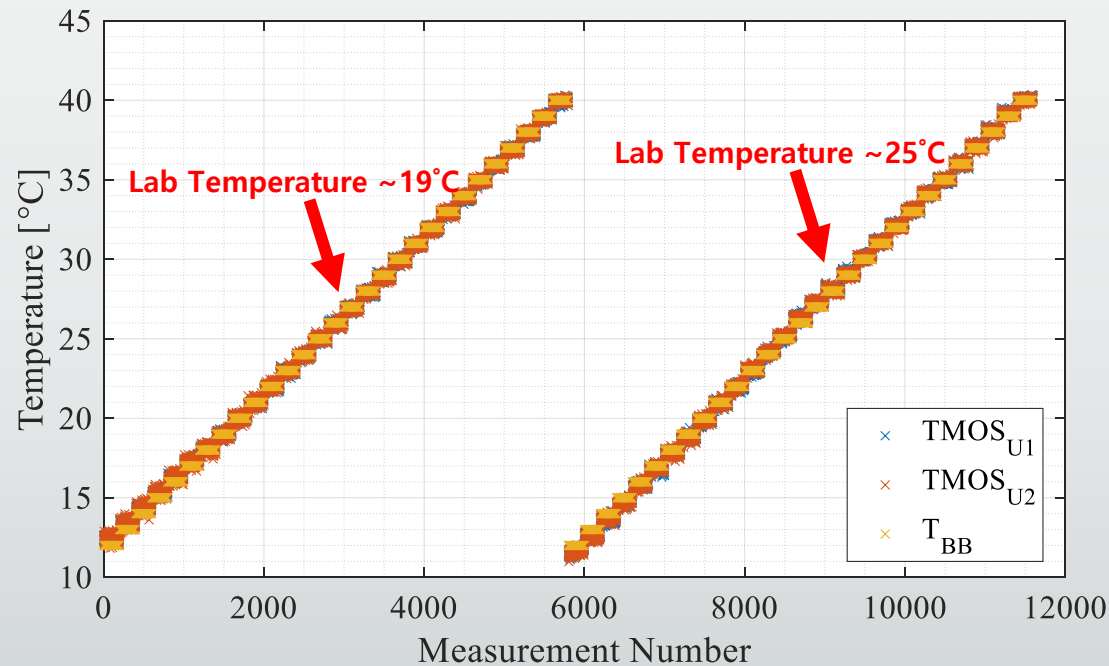


The Role of the CO₂ Narrow Band Pass Filter

- **Remote sensing of temperature** requires that the measured object will behave like a blackbody with known emissivity
- **The air is transparent to the visible and NIR radiation**
- **CO₂ is always present in the atmosphere as a greenhouse gas, with at least 400 PPM concentration**
- **The CO₂ in the atmosphere** absorbs the 4.26um radiation within an optical path of ~20 meters
- Hence, at this wavelength, the air may be treated like a blackbody with emissivity close to 1

The TODOS Technologies Air Sensor Calibration in The Technion Lab

- The calibration is based on **CI-SYSTEMS** extended area Blackbody
- Performed at two lab temperatures; with no environmental disturbance
- **The two units measure the same temperature** with an accuracy of 0.7°C and precision of 0.3°C : **indicating the quality of the sensors; to be improved by filtering**



The Measurement Reference -IMS

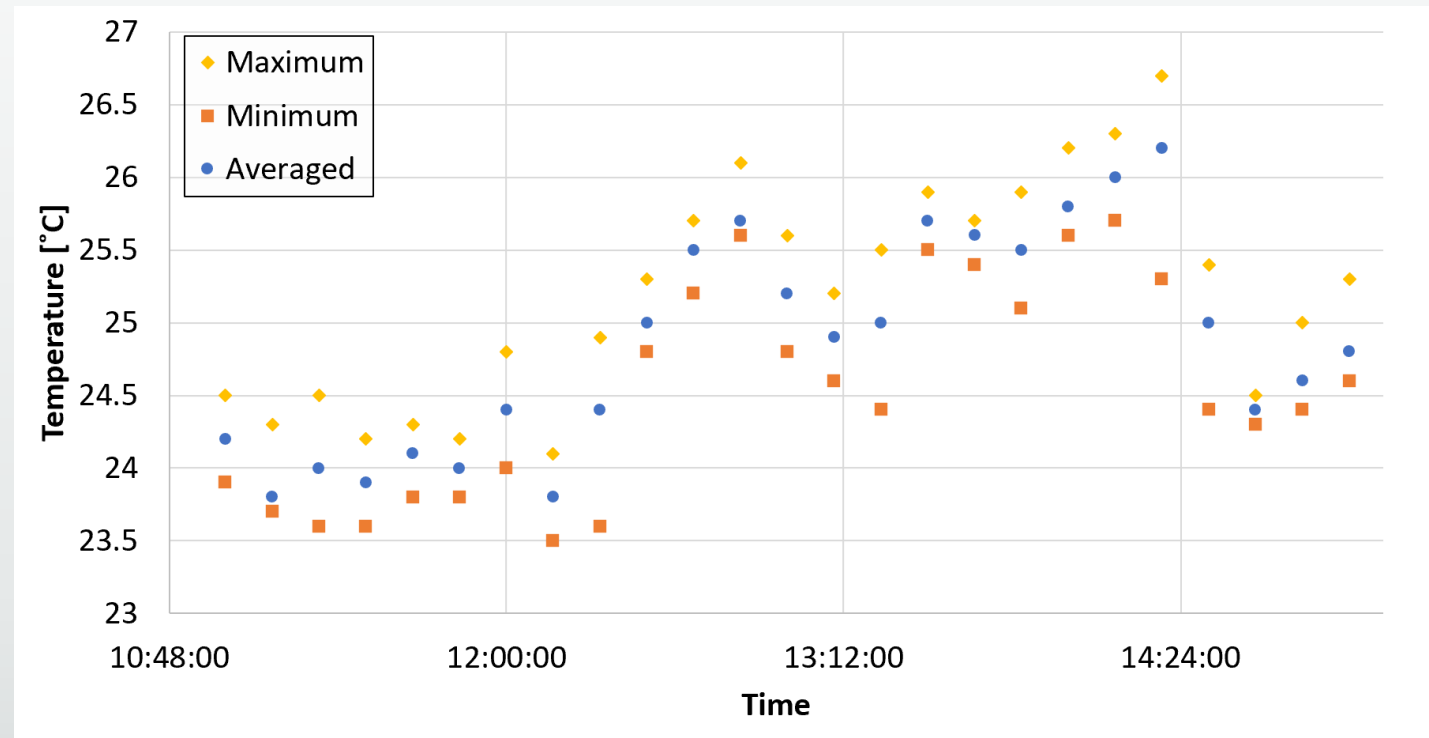
- The Israeli Meteorological Service (IMS) located at Haifa, Israel Institute of Technology
- The temperature measurement is inside a passive radiation shield
- Additional environmental parameters are measured simultaneously
- **TODOS measurement system, located adjacent in a small passive radiation shield, 3D printed BOX, powered by battery**



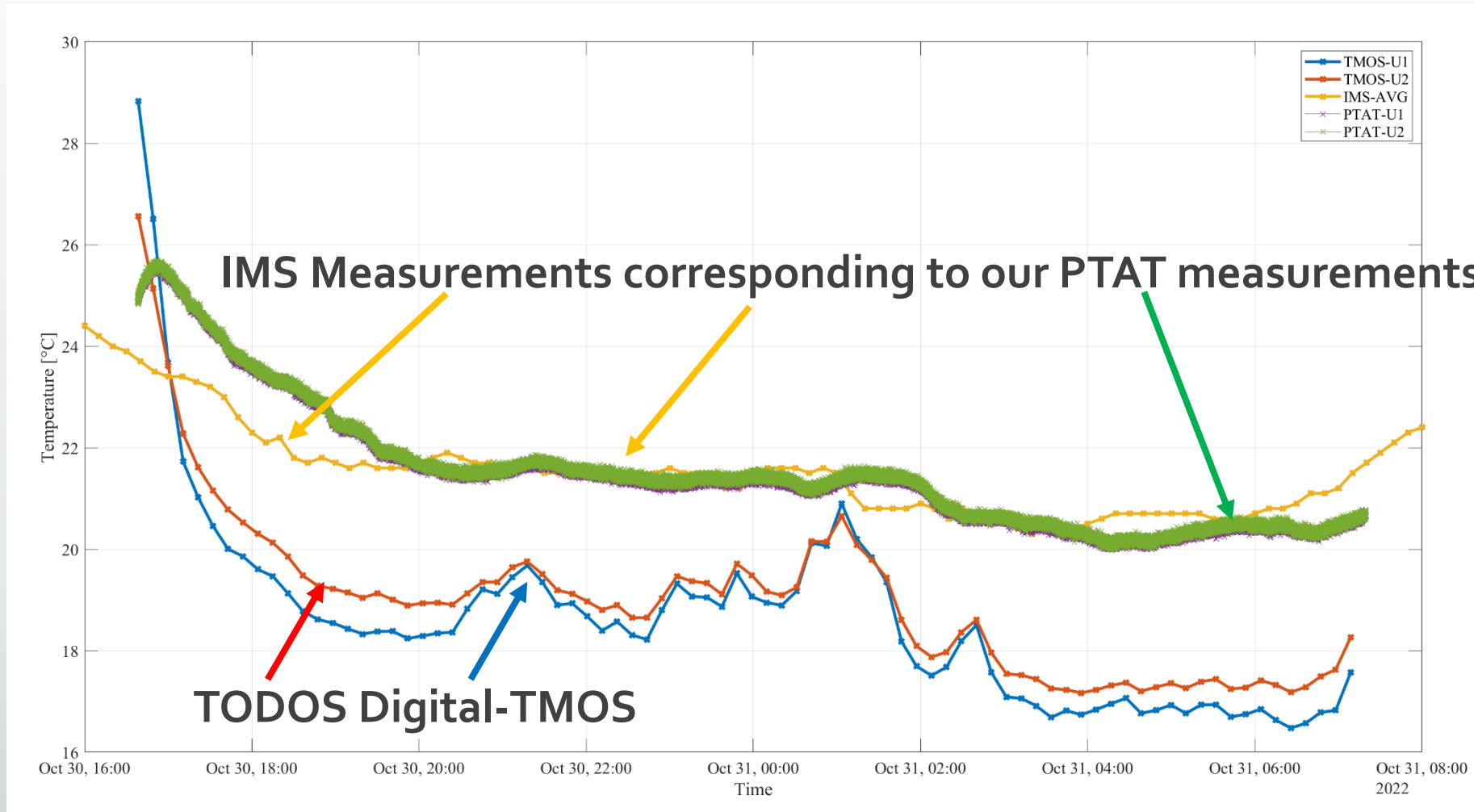
The Reference Temperature Measurements by The Israeli Meteorological Service (IMS) located at Haifa, Israel Institute of Technology, provides a 10 minutes processed data:

- The **averaged** temperature
- The **maximum** temperature
- The **minimum** temperature
- **Weather was fluctuating between clouds and direct sunlight**
- **the wind speed was changing**
- **Additional measured parameters:**
 - **Wind Direction (degrees)**
 - **Wind Speed (meter/sec)**
 - **Radiation: direct, dispersed, global**

- The measurement performed at 20/10/22
- **Noon Time**

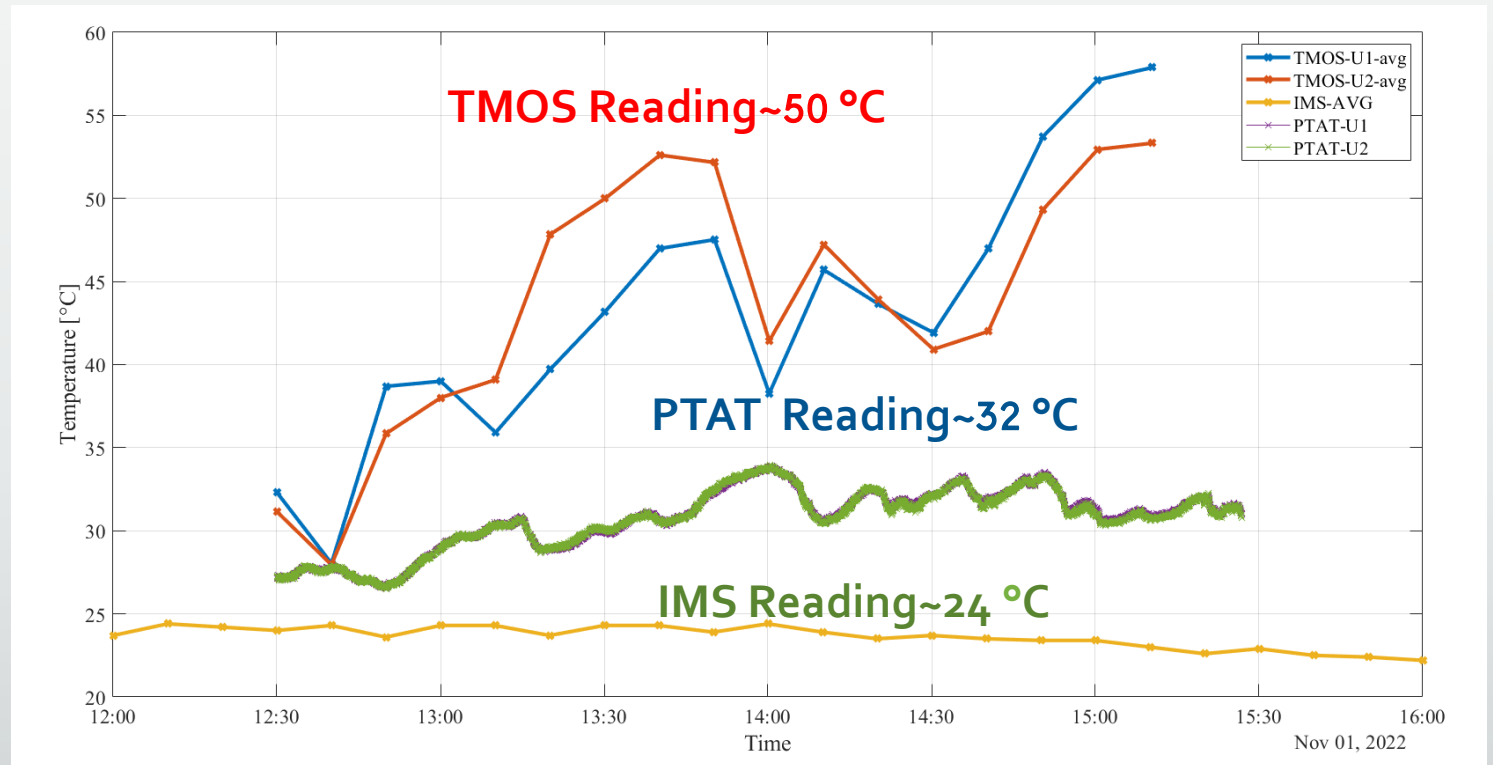
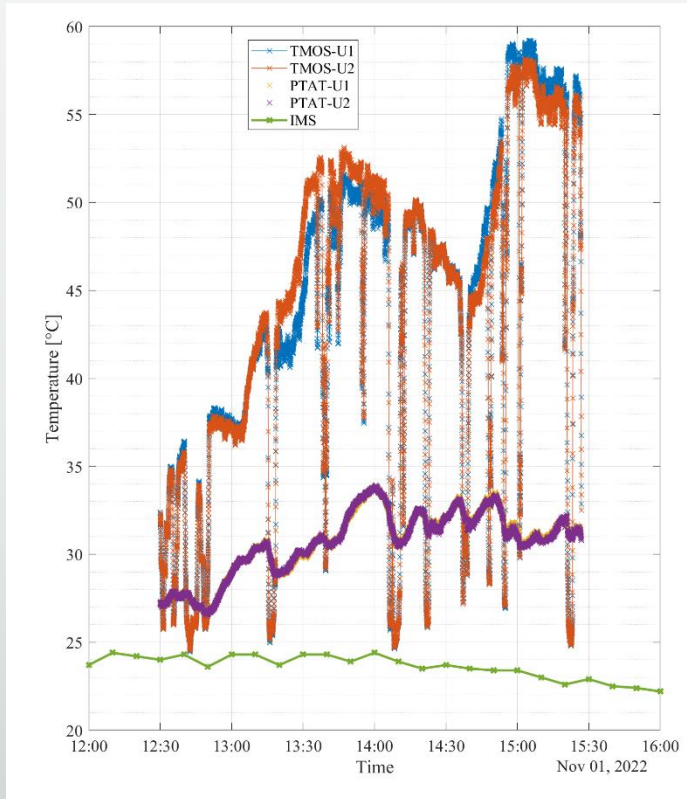


The Measurement Results of TODOS AIR TEMPERATURE BOX 30-31 October 2022; Overnight PTAT-temperature circuit proportional to absolute temperature



The Measurement Results of TODOS AIR TEMPERATURE BOX

- **Measured at daytime; 2/1/2022**
- **Affected by sun radiation effects**
- **RAW DATA readings!**
- **Filtered readings!**
- **What are we measuring?**



Our interpretation of the results

- **The effect of the passive radiation shield:**
Larger shields collect more sun radiation
The air inside the shield correlates with the sun
The measured temp. is the air temp. inside the shield
- **The smaller box is less affected (with the right BOX material)**
The PTATs measure the air inside the box
Only the Digital TMOS measures by remote sensing the True Air Temp.
- **We measure the average of the sun, sky and air**
- **What info is needed?** depends on the use case



Summary and Looking Ahead

- Accurate air temperature measurement remains challenging, despite decades of research and development, requiring improved remote sensors
- These measurements will continue to be challenging given the tradeoffs between accuracy, power consumption, and costs
- The radiation shield is an essential part of the measurement

OUR BOTTOM LINE:

- With the advent of **TODOS - Technologies sensor technology** and **machine learning techniques**, the performance of air temperature sensors will keep improving (high performance/ reduced cost)

Thank you for your Attention Questions?

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Derivative of STM Product - STHS34PF80
[link](#)



Acknowledgement:

