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On the Potential of Wireless Sensor Networks for the In-Field Assesment of Bio-Physical Crop Parameters

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SenseApp, LCN, Edmonton – 2014/09/08

Outline

1. Motivation
2. Background
3. Setup
4. Evaluation
5. Conclusion

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Precision Farming / Smart Agriculture

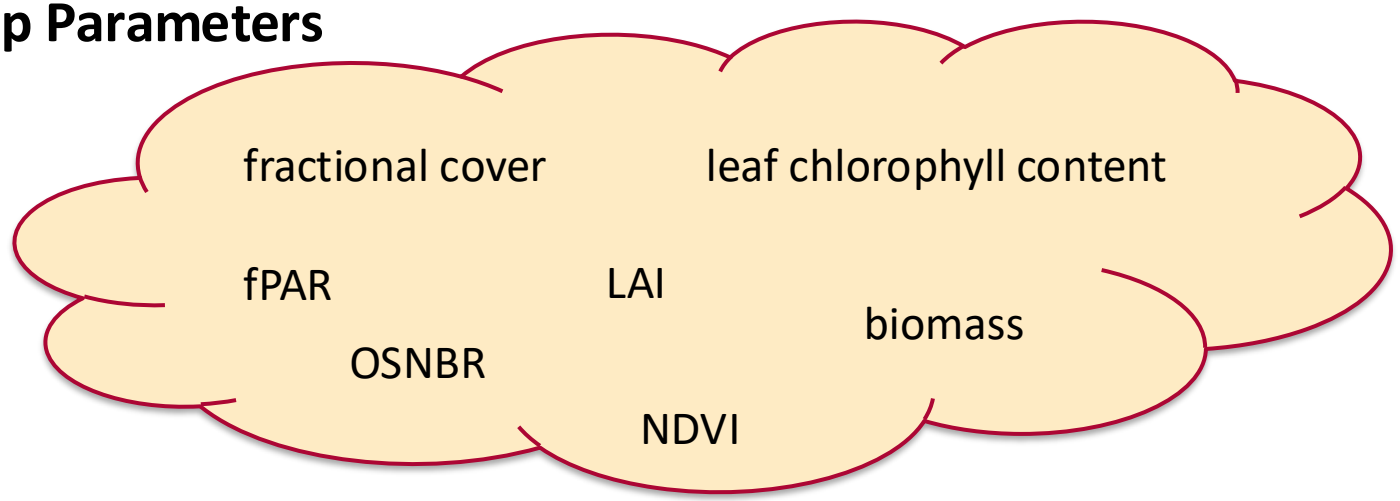
- crop yield optimization
- adopted crop types due to climate change
- precise fertilization
- precise irrigation
- precise identification of crop diseases
- precise plant protection
- precise harvesting

Demand for situational awareness

- in-field
- global economy:

  securing supply on world market
- **How to provide situational awareness?**
- **How precise is precise?**
- **How to measure crop parameters?**

Crop Parameters

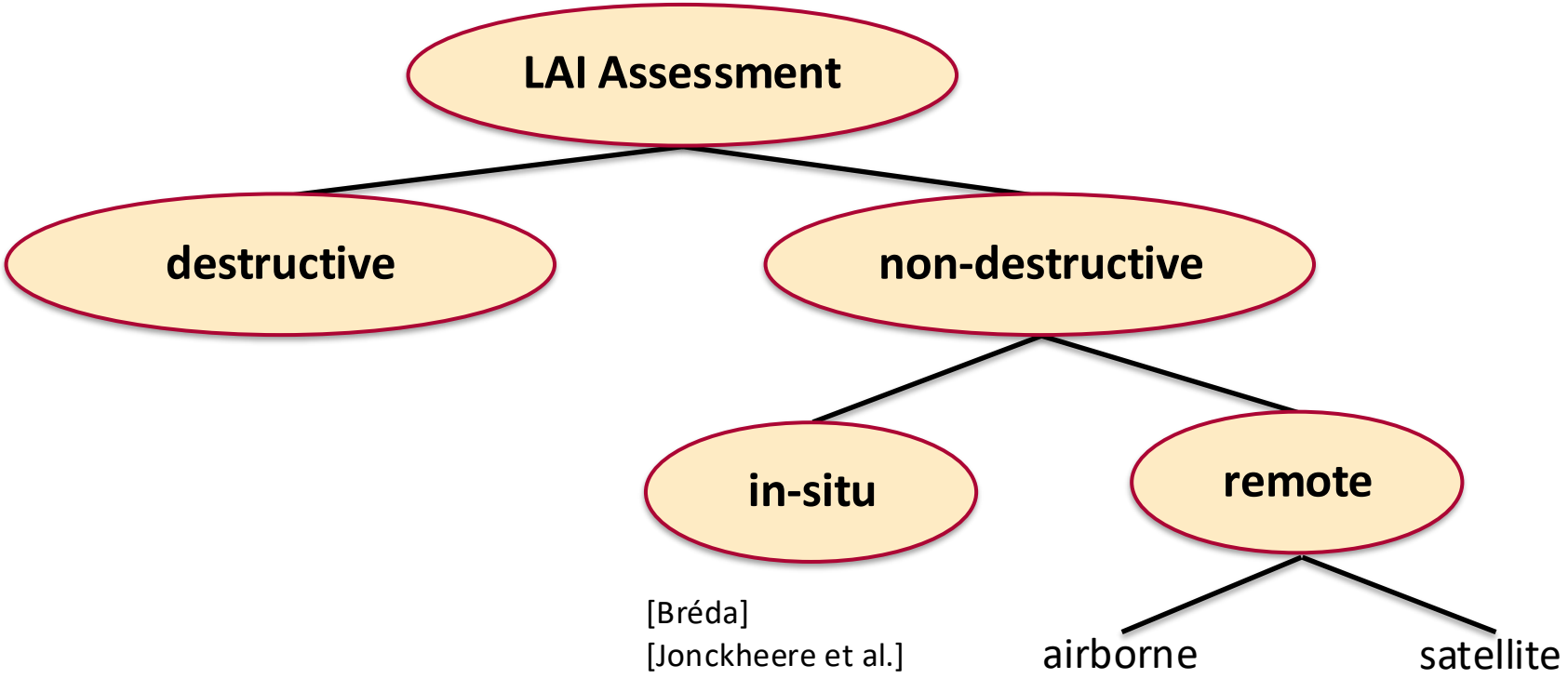


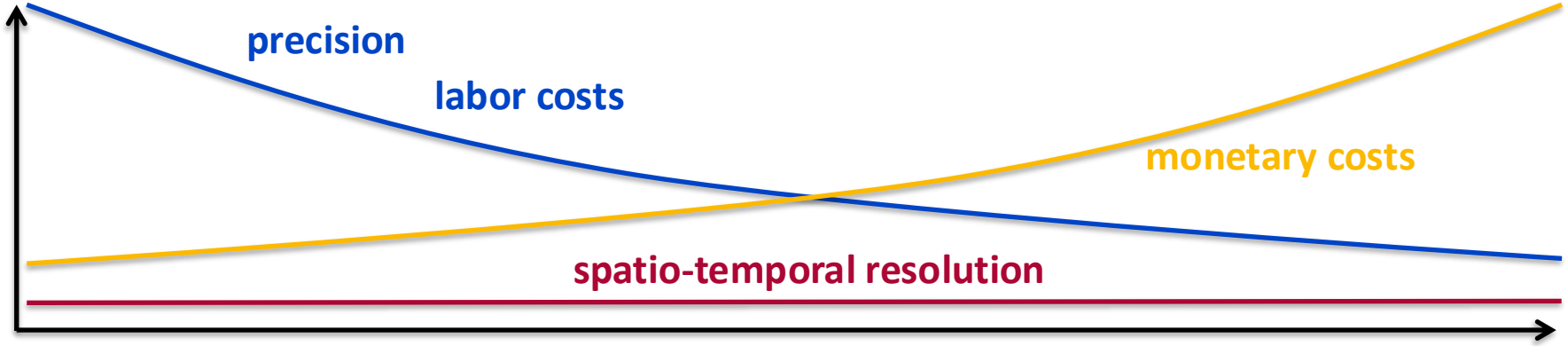
Leaf Area Index (LAI)

- key variable for models in climatology, meteorology, ecology, and agronomy
- indicator for photosynthetic performance of plants
  - yield-limiting processes caused by plant diseases / mismanagement

$$LAI = \frac{\text{green leaf area}}{\text{ground surface area}}$$

Motivation: Classification of Conventional Approaches





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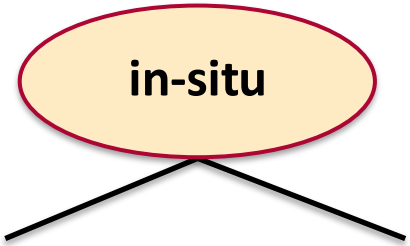
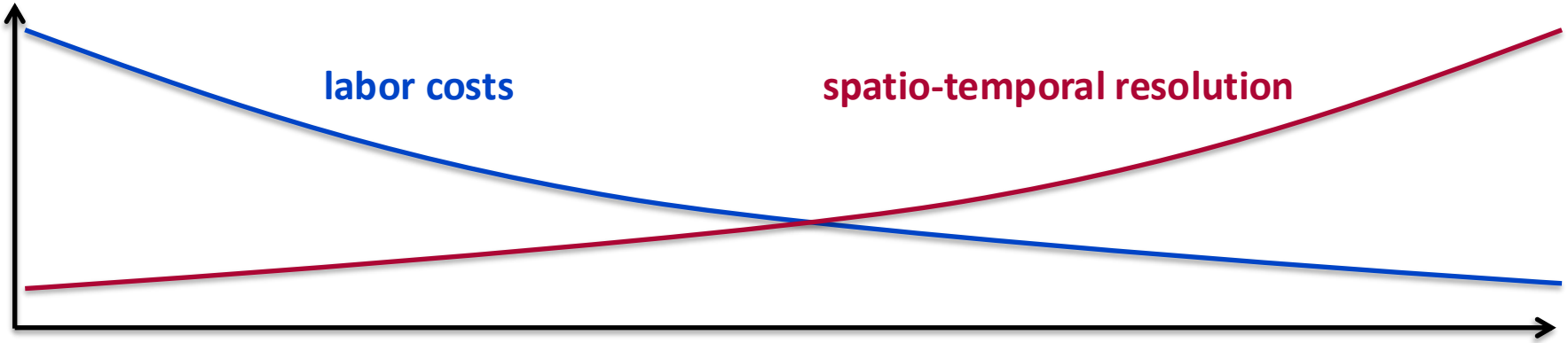


conventional approaches:

- LAI-2000/2200 (LI-COR)
- SunScan (Delta-T Devices Ltd.)
- ...

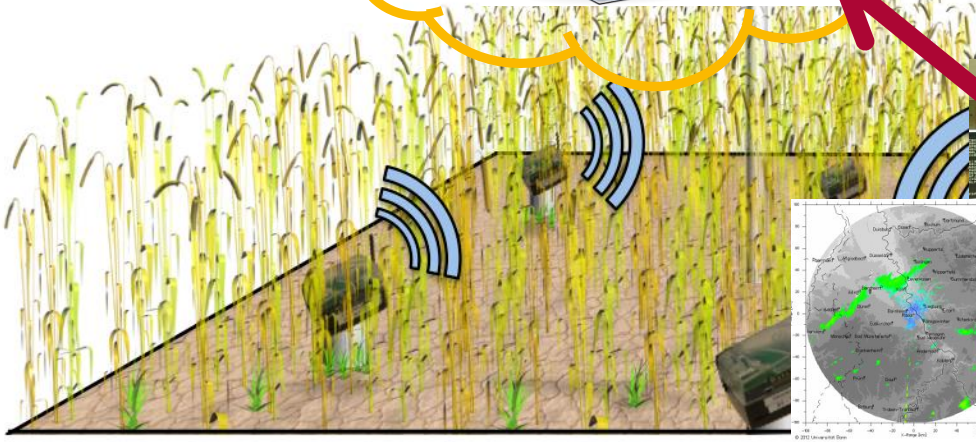
Wireless Sensor Networks (WSNs)



precision?

Motivation: Vision of Precision Farming

remote sensing support



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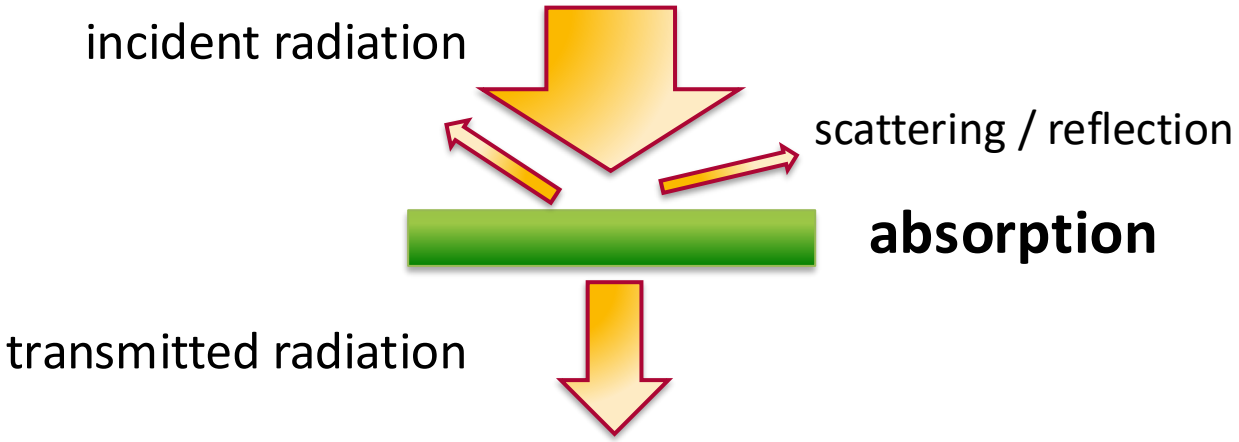
Beer-Lambert law (1852)



Monsi-Saeki model

$$L = -\frac{1}{C} log\left(\frac{B}{A}\right)$$

below canopy reading

above canopy reading

Transmittance

M. Monsi and T. Saeki, "On the Factor Light in Plant Communities and its Importance for Matter Production," *Annals of Botany*, vol. 95, no. 3, pp. 549–567, 2005

WSN Application:

- Sensors:
  - Hamamatsu S1087 PAR Sensor
  - Senserion SHT11 (MTS400 Sensorboard)
  - PerkinElmer VT900
- Platform: TelosB
- Software: TinyOS

- **Data Collection:**
  - PAR + temperature + humidity
  - sampling rate: 3 Hz
  - 17 samples per packet
  - broadcast every 6 s
  - centralized LAI processing

Distributed setup

Memory Footprint:

ROM	16.932 kB	< 35 %
RAM	780 byte	< 8 %

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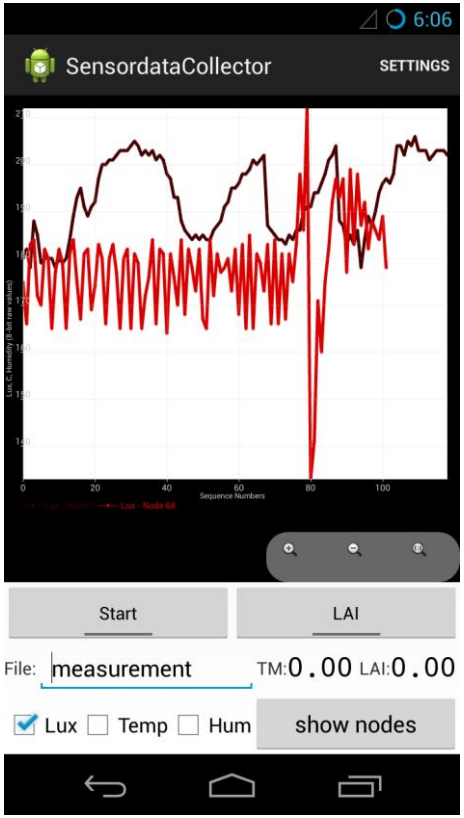
Mobile Data Assessment

- Android application
- data sink with LAI processing



Direct comparison

for Evaluation of sensor potential

LI-COR LAI-2200 Plant Canopy Analyzer

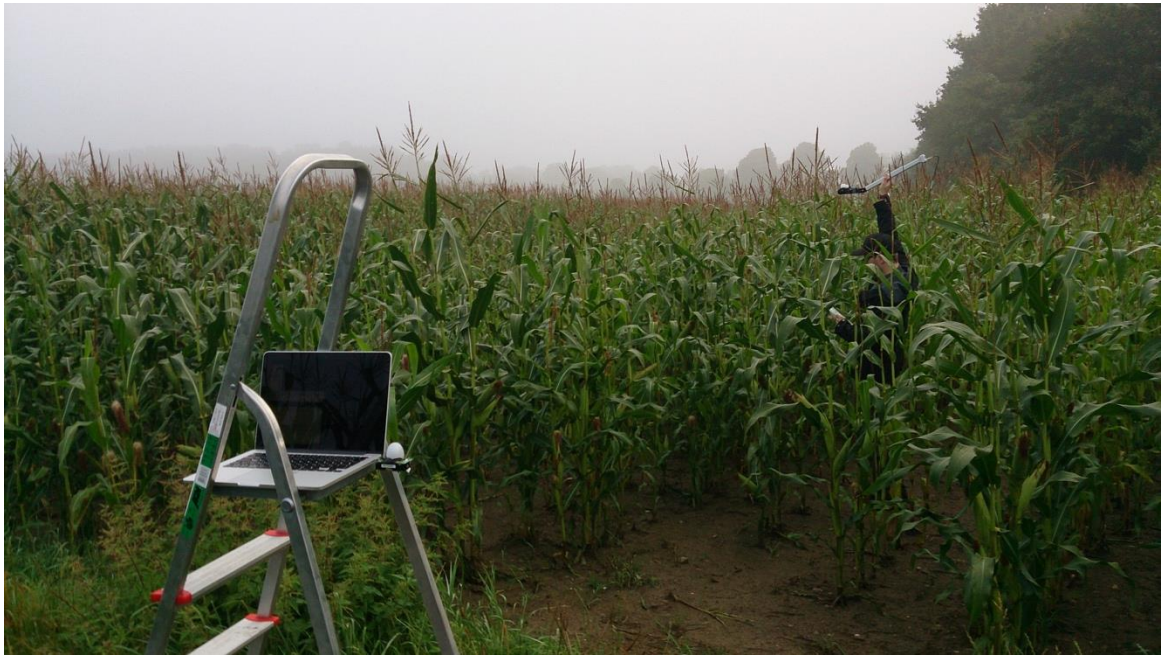
- standard instrumentation as reference device

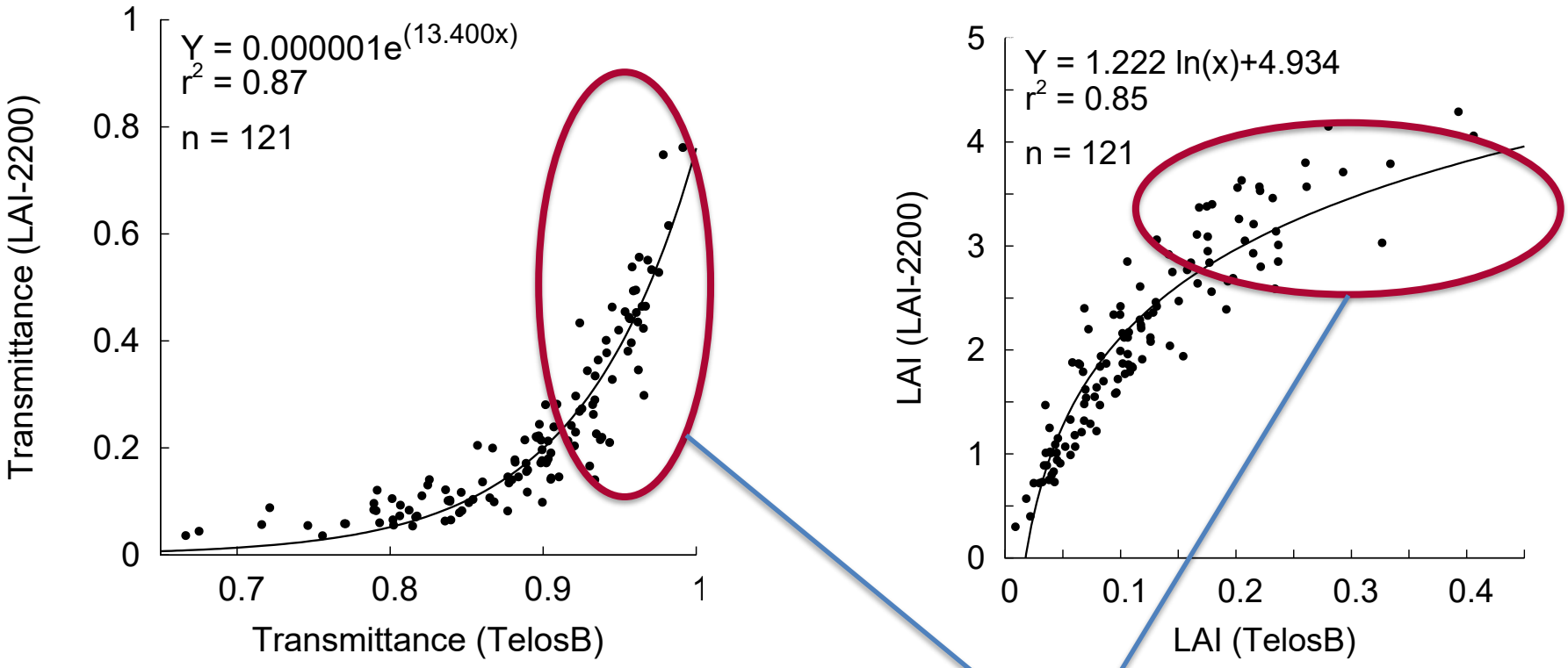
- Study area:
  - maize field
  - Osnabrück, Germany
- July – October, 2013
- Stable cloud cover → diffuse lightning conditions

Goal:

Validation of WSN potential

(sensing accuracy and correlation to LAI2200 estimates)





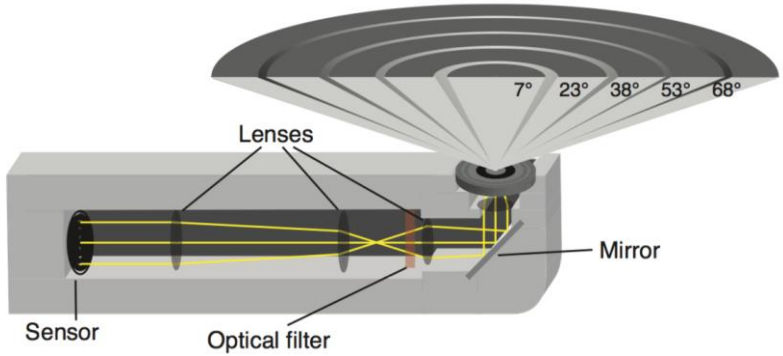
against expectation:
non-linear correlation

WSN sensors not appropriated

Why?

LI-COR LAI-2200 properties:

- 5 rings
- 148° field-of-view
- wavelength range: 320-490 nm



Weighting factors

$$L = 2\int_0^{\pi/2} -\frac{\overline{lnP(\theta)}}{S(\theta)} sin\theta d\theta = 2\sum_{i=1}^{5} \overline{K_i} W_i$$

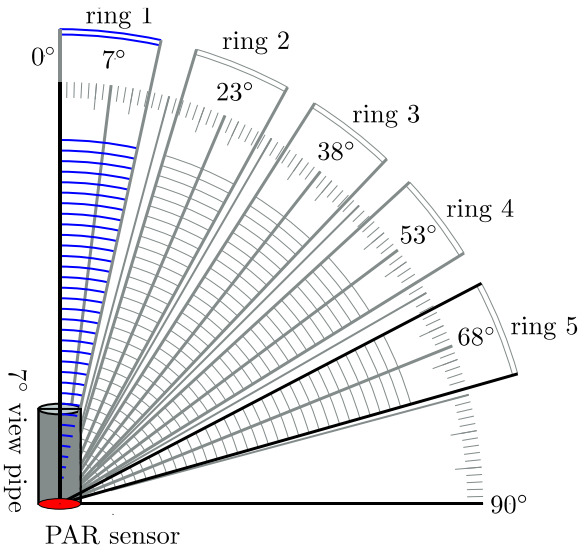
Transmittance

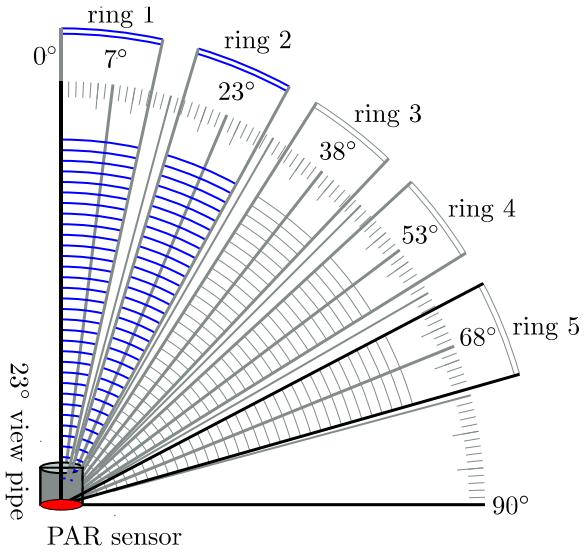
$$\overline{K_i} = \frac{1}{N_{obs}} \sum_{j=1}^{N_{obs}} \frac{-ln\left(\frac{B_{ij}}{A_{ij}}\right)}{S_i}$$

LI-COR, "LAI-2200 Plant Canopy Analyzer - Instruction Manual," http://www.licor.co.za/manuals/LAI-2200 Manual.pdf, Last checked: August 13, 2014.

Reason of Discrepancy:

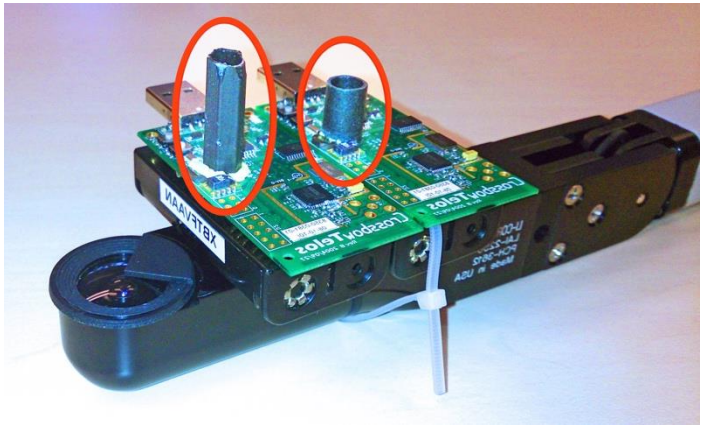
Different field of views and corresponding weighting of rings



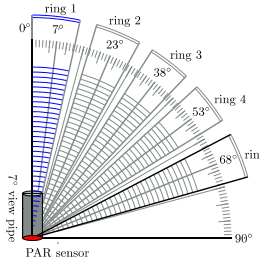


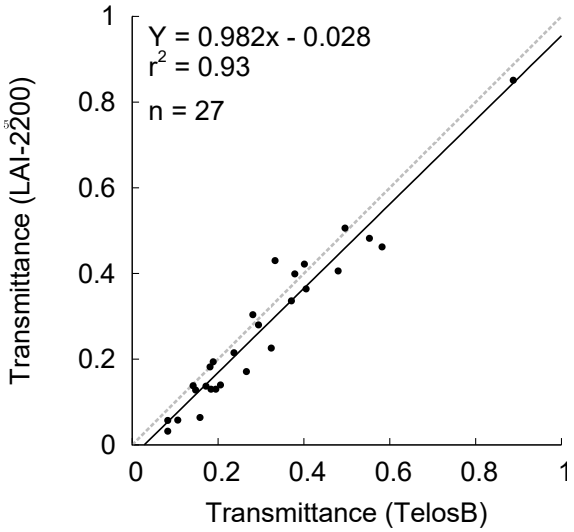
our approach:

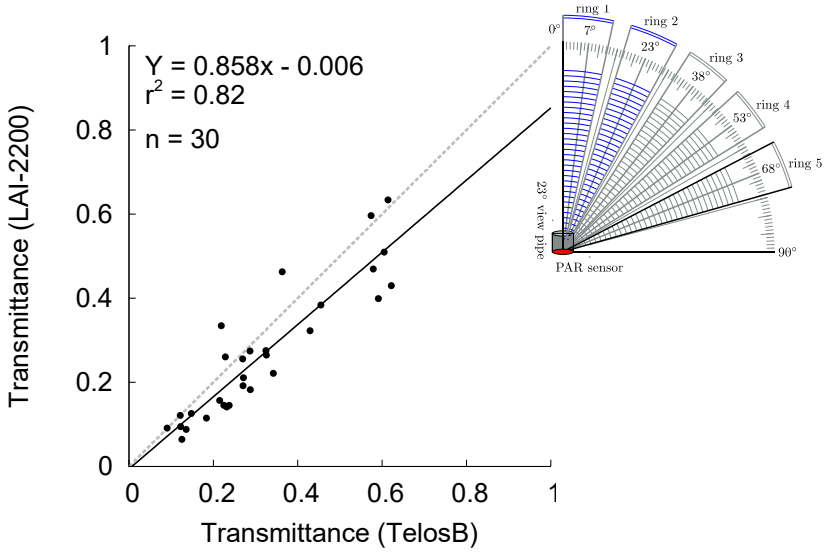
View Pipes



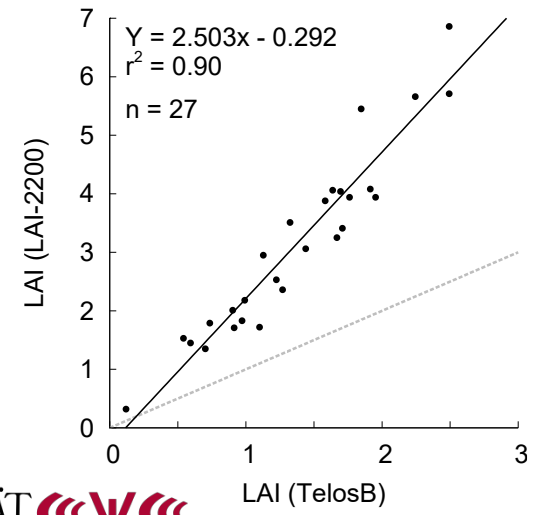
Evaluation: Impact of View Pipe Approach

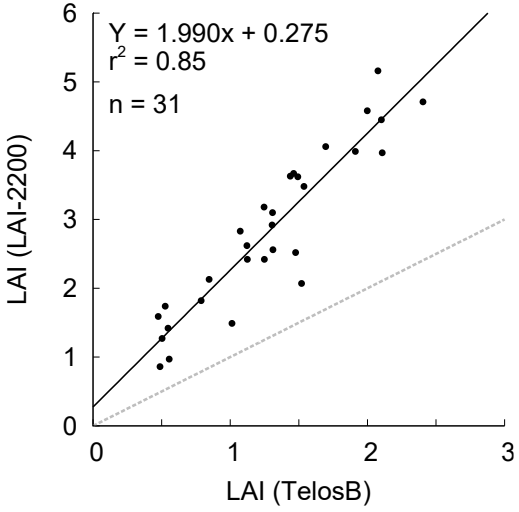






strong linear correlation with appropriate accuracy





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Conclusion

- **LAI assessment as foundation of Geo-WSNs for precision farming**
- **View Pipe concept** to enhance the potential of COTS devices (TelosB)
- **Promising results** by direct comparison
  - (clear linear relationship for 7° and 23° LAI)
- **Drawbacks:**
  - no upper bound
  - multiple sensors required for “full” (=68°/5 rings) LAI

Is it possible to achieve a sufficient accuracy as well as a linear correlation with a minimal set of sensors with specific view pipes?

Future work:

- destructive LAI measurements
- long-term deployment
  - large-scale
  - energy-efficiency
  - time synchronization
  - data preprocessing / aggregation

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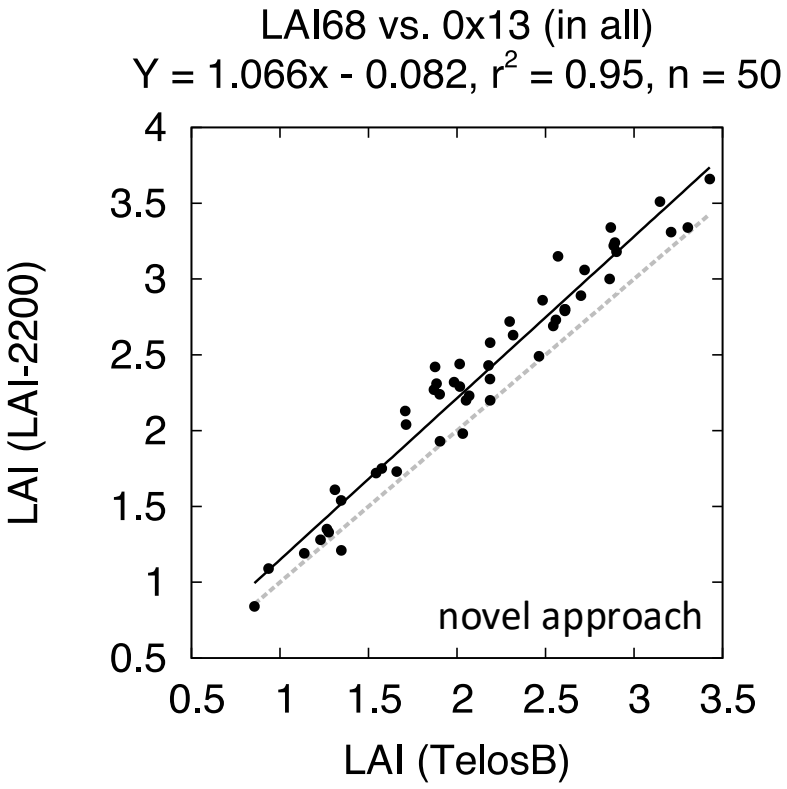
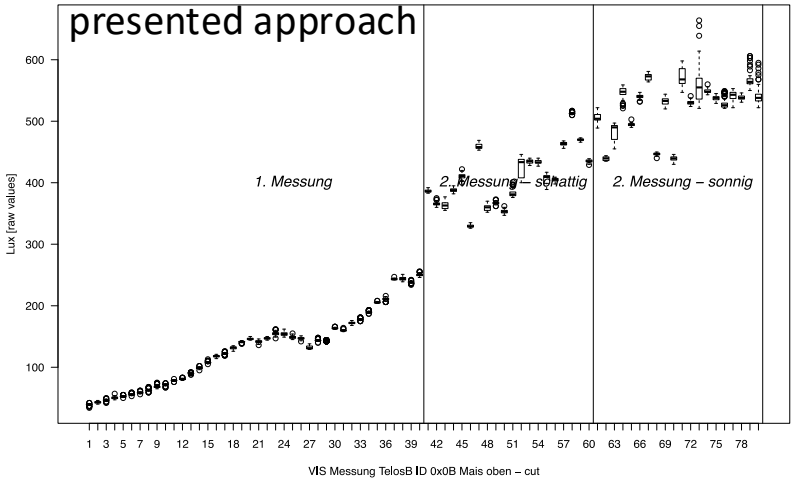
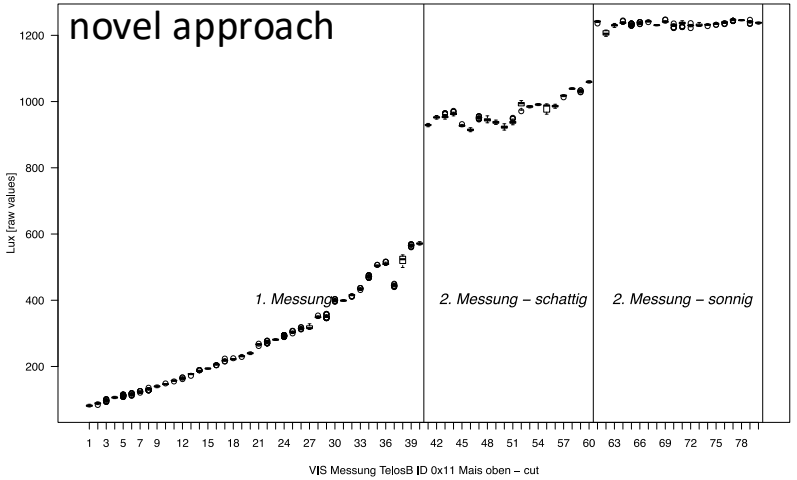
novel approach:

- slight modification
- more robust PAR measurements
- higher LAI correlation
- comparable LAIs

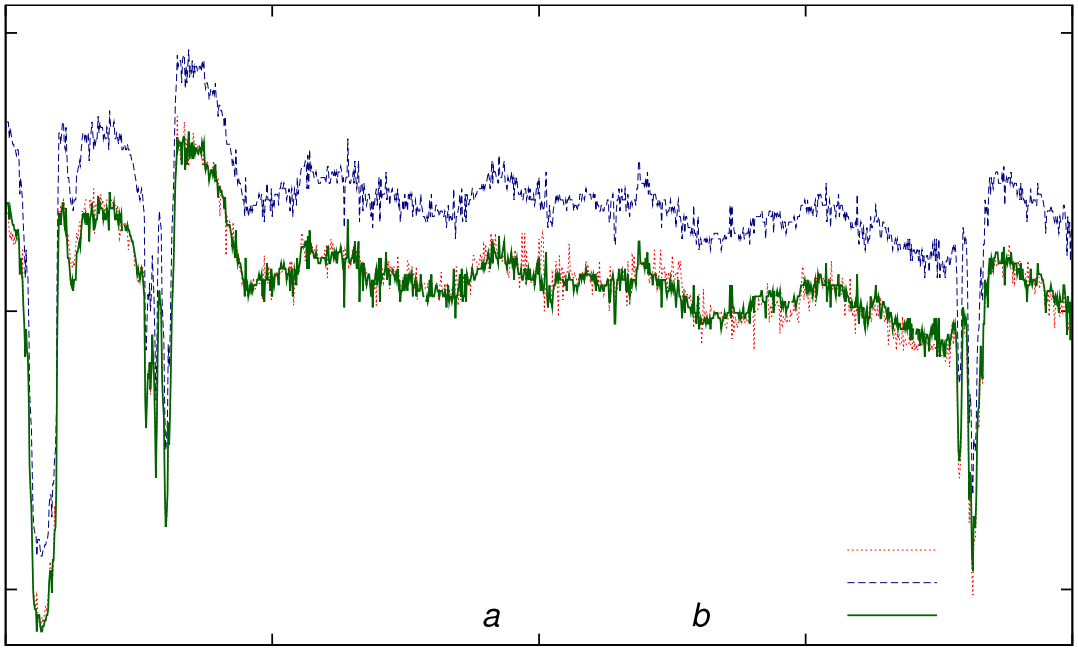






This work was supported by the ”Stifterverband für die Deutsche Wissenschaft” (H170 5701 5020 20951)

Calibration using Pearson product-moment



L.Mo,Y.He,Y.Liu,J.Zhao,S.-J.Tang,X.-Y.Li,andG.Dai,"Canopy closure estimates with GreenOrbs: sustainable sensing in the forest," in *Proc. of the 7th ACM Conference on Embedded Networked Sensor Systems (SenSys '09)*, Berkeley, CA, USA, 2009, pp. 99–112.

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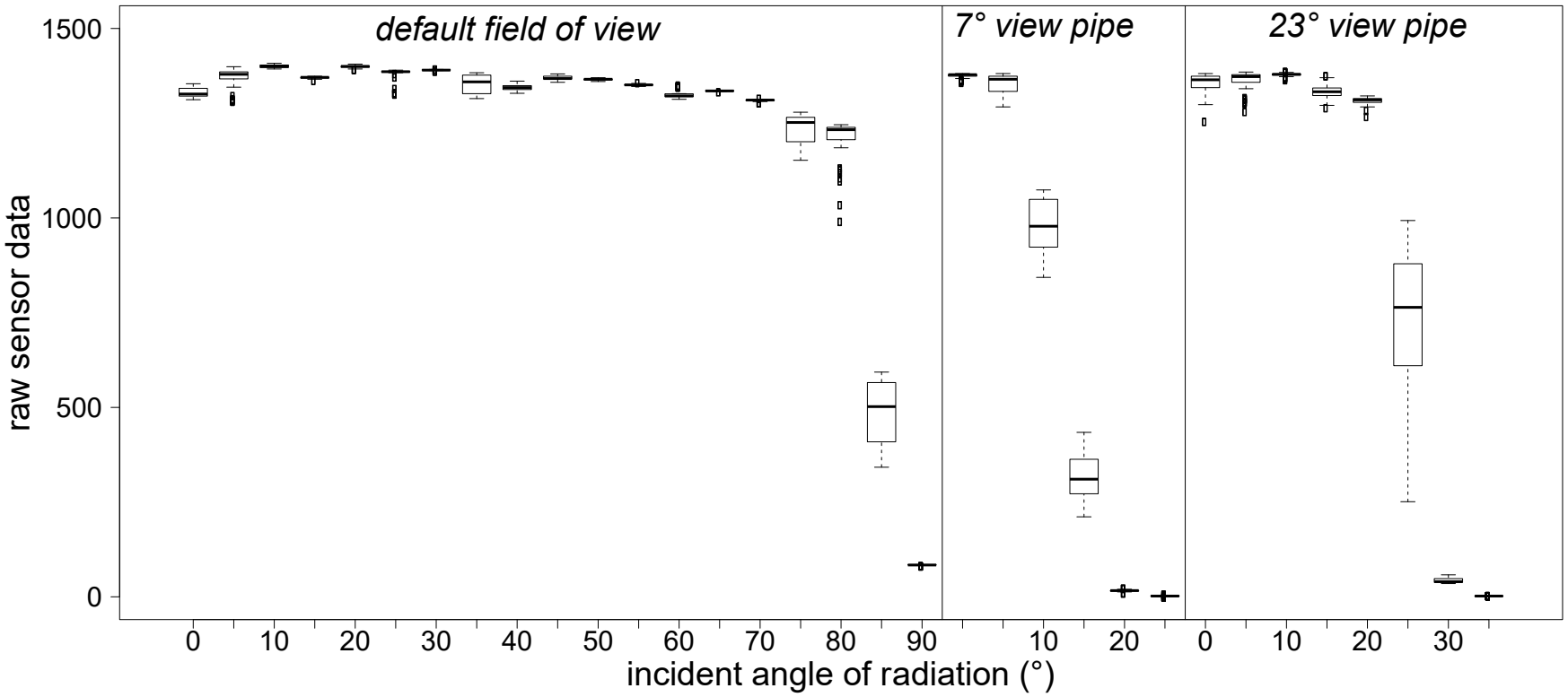

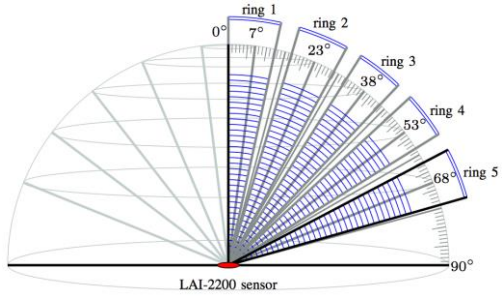

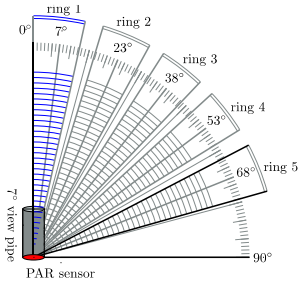

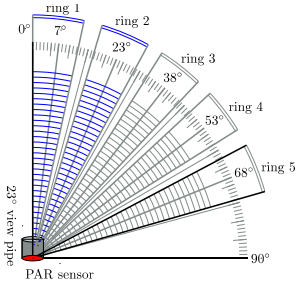

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