Quantifying directional effects of land surface temperature in forests: an experimental approach across scales

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Validation sites for forest ecosystem stress products

T-SEC project: *energy balance modelling using TIR remote sensing in complex environments:*
→ biosphere (forests, arctic tundra), cryosphere and hydrosphere

Where should we place our sensors, facing what direction/slope?

How much will these instruments be impacted by directionality (lessons learned in the optical domain) and are mechanisms behind directionality the same at TRISHNA scale?

How will directionality at the tower scale impact validation of TRISHNA ecosystem stress products?

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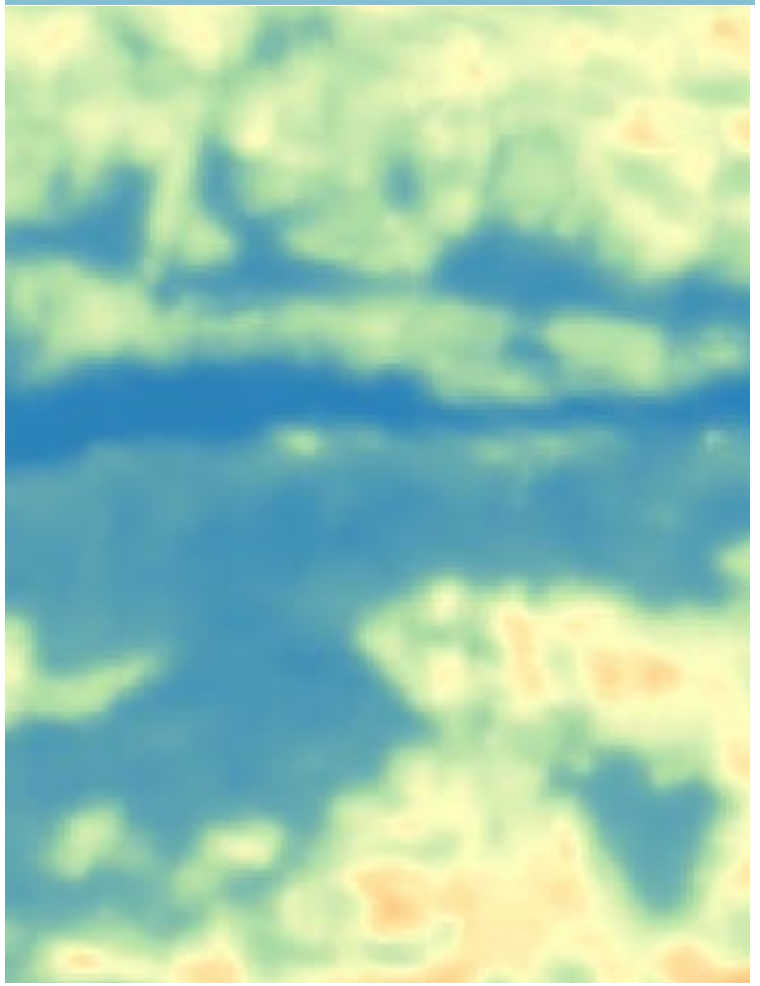
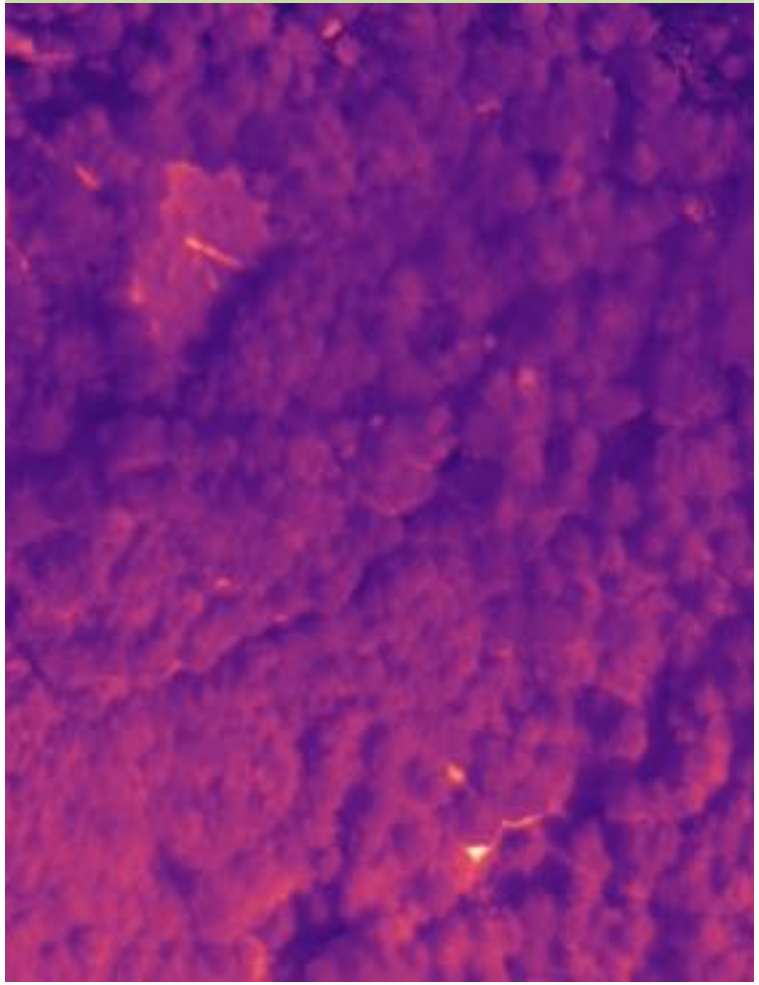
Measuring directionality in forests at different scales?

Satellite observations

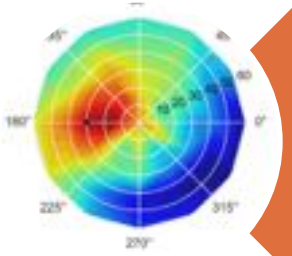


UAV / Airborne



In-situ observations

Measuring directionality in forests at different scales?



Measure directionality in a “standard way” across scales over forests

Tease apart components of directionality in forests and how they differ with scale:

1. Structure
2. Plant physiology

Investigate what implications this might have on validation of satellite products with in-situ data

Solution ?

Photo: RSL

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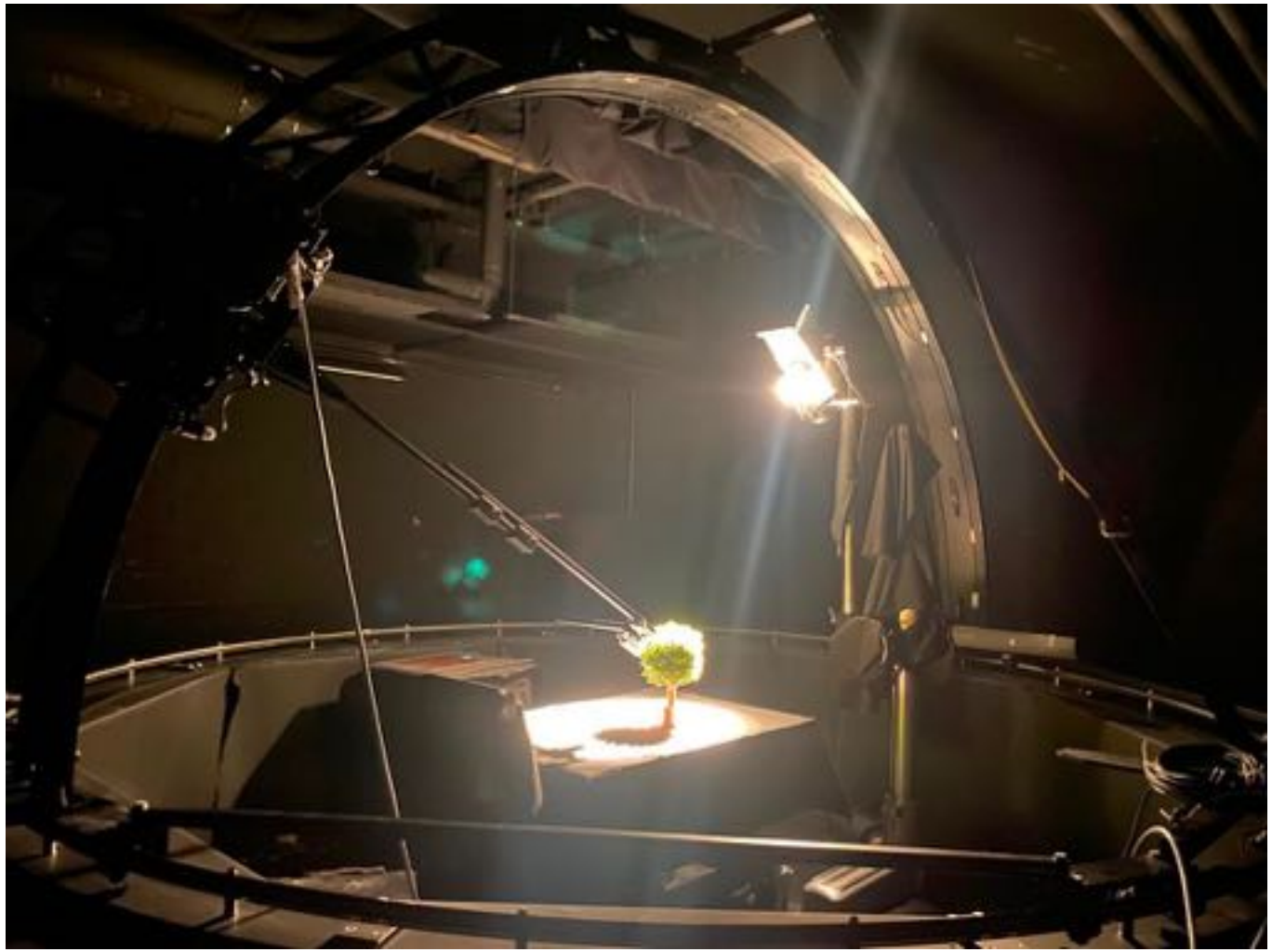
Goniometer Measurements: Scaling forests down

Can we **reconstruct miniature forests** scaled down to the goniometer footprint whilst observing the **same structure at in-situ and TRISHNA footprint**?



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Miniature forests in the goniometer FOV

Jacob et al (2008)

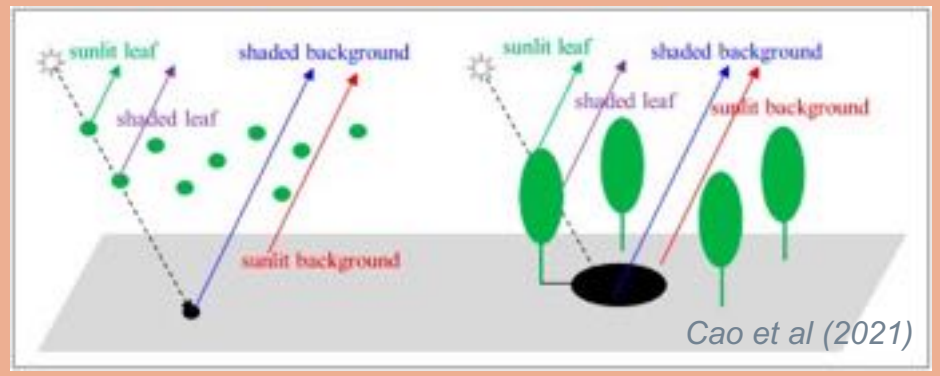
1. Multiple scattering (continuous scenes or volumetric scattering)

→ Isotropic scattering, dominated by reflected, transmitted and emitted radiation

2. Geometric optical scattering

→ Dominated by shading effects and component temperatures

3. Contributions of structure and plant functioning



Cao et al (2021)

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"Structure only" forests in the goniometer FOV

Scene	Type	Dimensions Diameter: D, Height: H	Scatterer size / height	Fractional coverage
A	Volumetric	0.5 x 0.5 m	Height : 0.5 cm	-
B	Volumetric	0.7 x 0.5 m	Height : 0.4 cm	-
C	GO	Crown D: 0.1 & 0.15 m	Scatterer : ~ 1 cm	~1
D	GO	Crown D: 0.1 & 0.15 m	Scatterer : ~ 1 cm	0.4
E	GO	0.15 m (D) x 0.3 m (H)	Scatterer : ~ 1 cm	0.17
F	Background	-	-	-

- **Continuous/volumetric "structure only" forests:** 2 types of artificial grass surfaces
- **Discrete/GO "structure only" forests:** Spheres ranging from 10-22cm diameter (size selected based on crown size of Laegern forest), fractional coverage : 0.17 – 1 to represent pointing radiometer at a single tree to full observation of Laegern (closed canopy forest)

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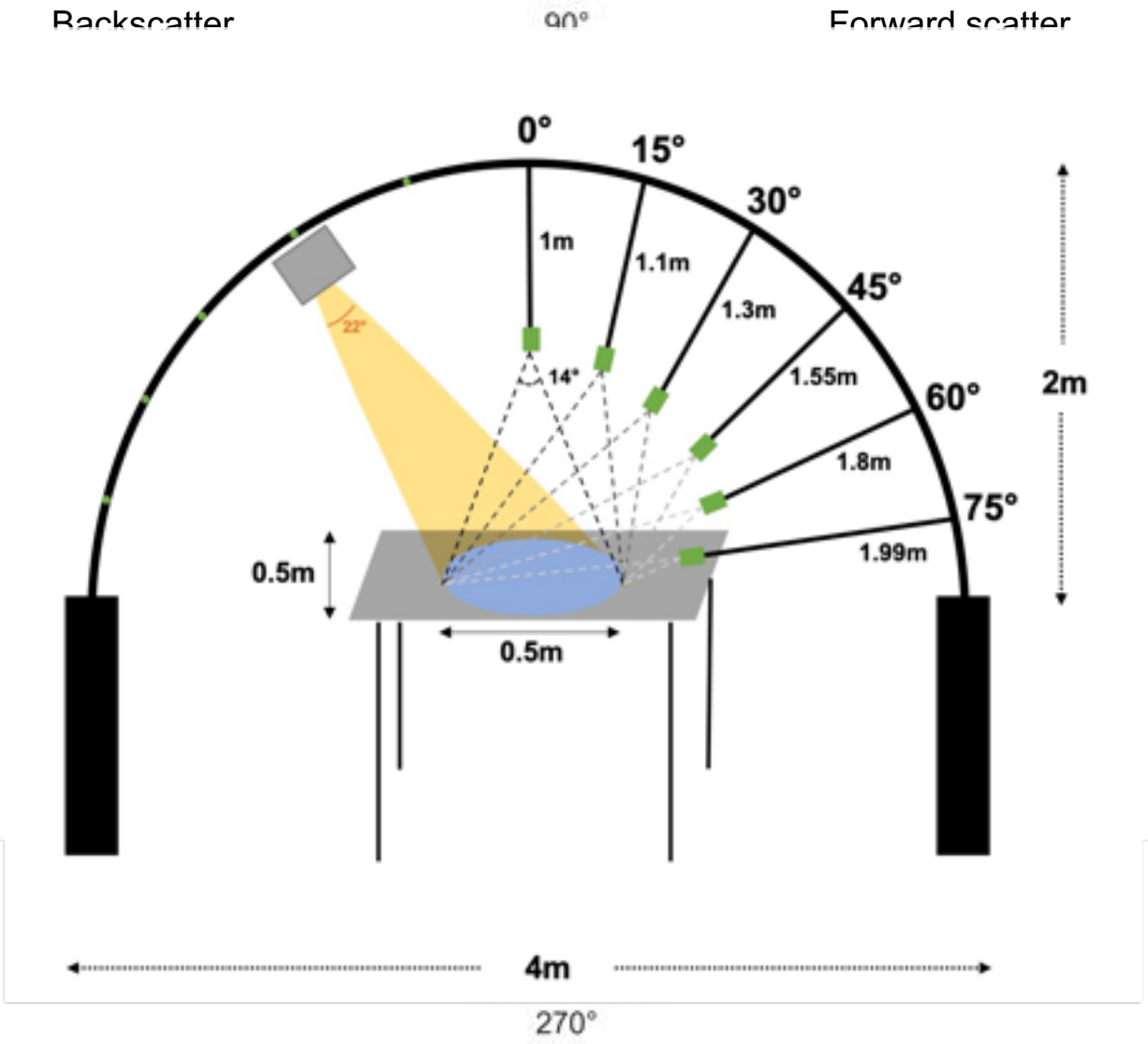
TIR Goniometer Measurement Set-up

Instruments

- Apogee SI 131 Ultra-narrow (Half FOV: 14°), 8-14μm
- Meteo station: air temperature and humidity
- Go-pro and NEC TIR camera
- Calibration at PMOD/WRC

Goniometer set-up

- Full hemisphere, VZAs 0-60°
- Measurement integration time = 10 seconds
- N measurements = 10 per angle
- Constant FOV: 0.5 x 0.5 m
- Stabilisation time of instrument in lamp (1-2 hours)
- Correction for ambient T and emissivity



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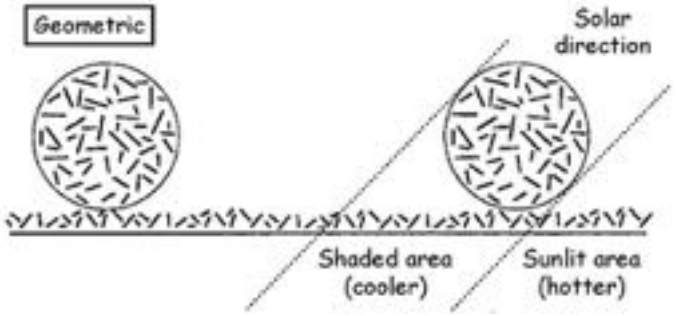
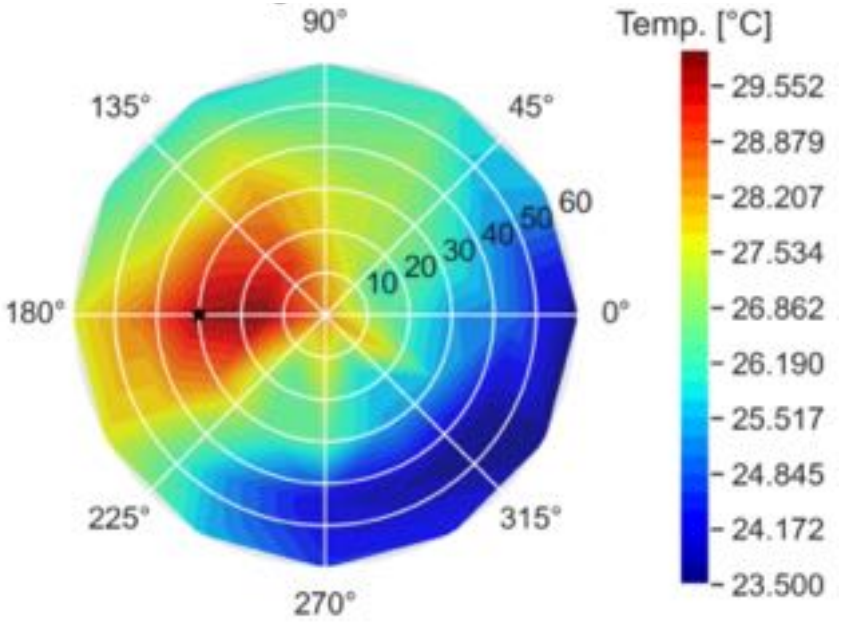
Geometric Optical scattering (Tower footprint)

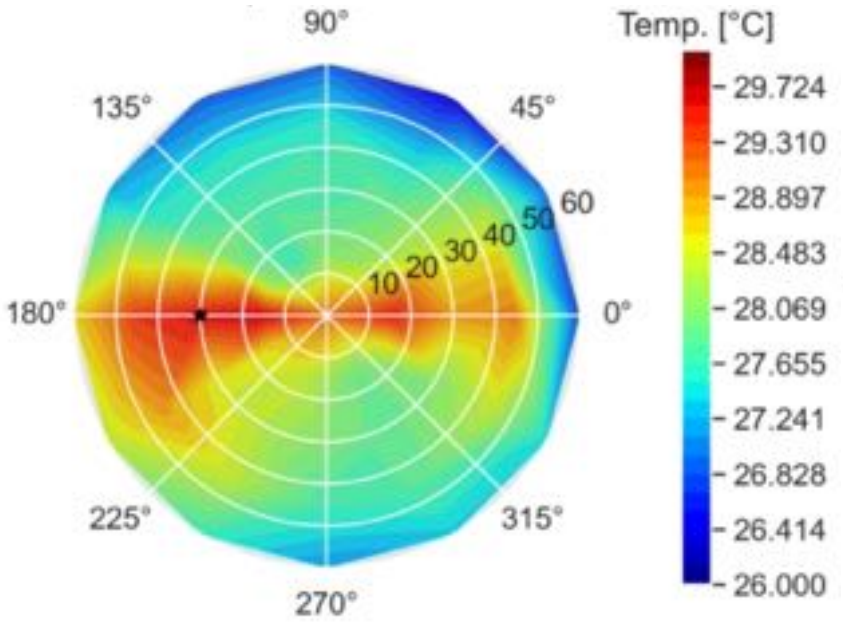


- Clear hot spot and shadowing in low and high fractional coverage (more likely scenarios for Laegern and Davos tower instrumentation)
- Medium fractional coverage results in hot spot + forward scattering in the principle plane

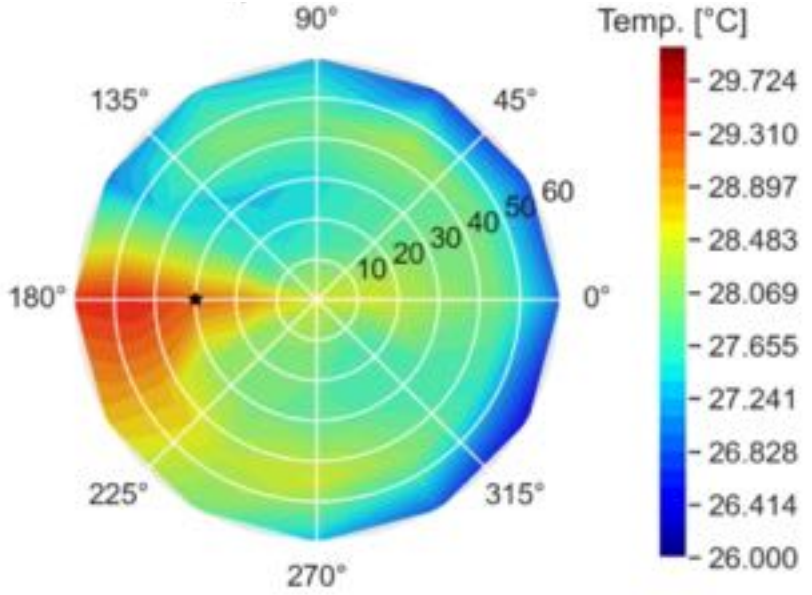
Scene E (FCOV = 0.17)



Scene D (FCOV = 0.4)



Scene C (FCOV = ~1)



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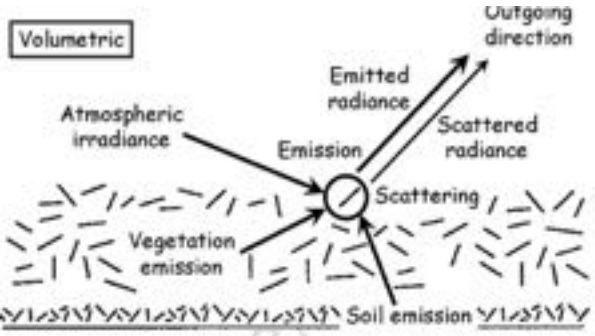
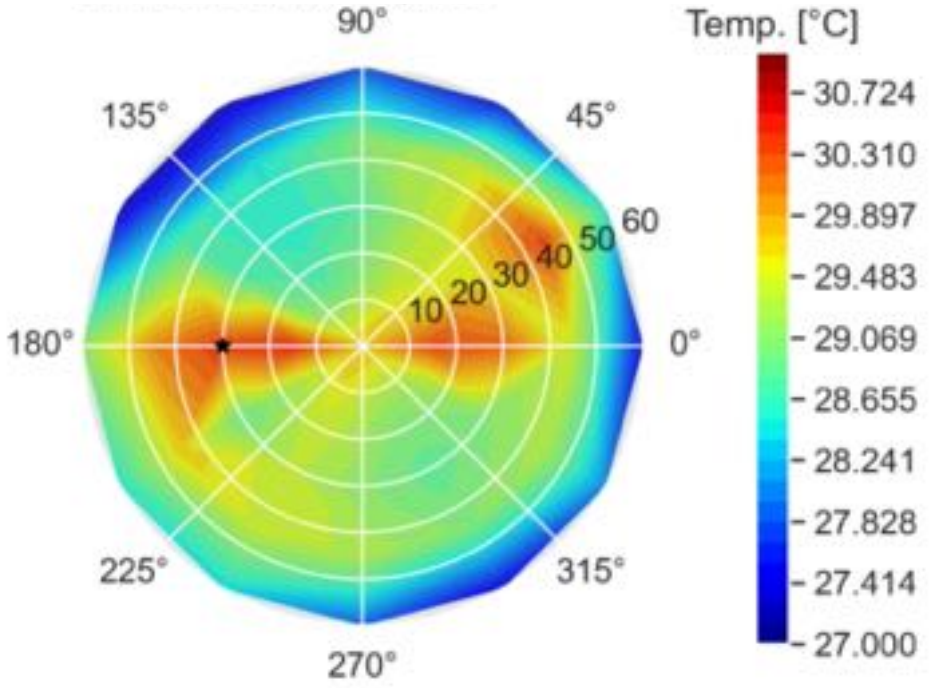
Volumetric scattering (TRISHNA footprint)

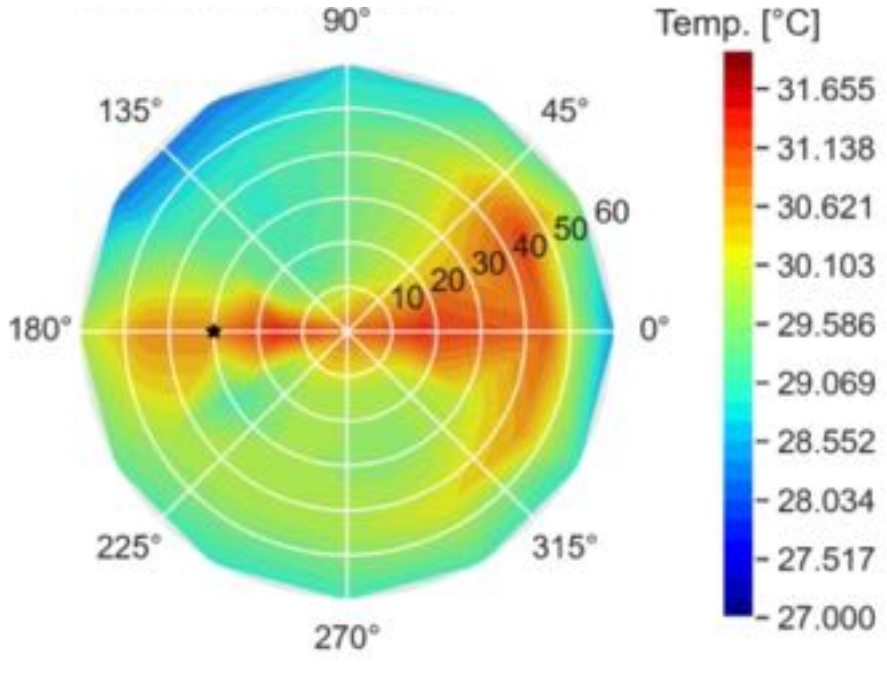


- Hot spot and scattering in the principle plane clearly evident, similar pattern for the two different scenes
- More shadowing at oblique angles for scene A (higher canopy height)
- Sensor related or “Leaf Angle Distribution” / orientation of the scenes?

Scene A



Scene B



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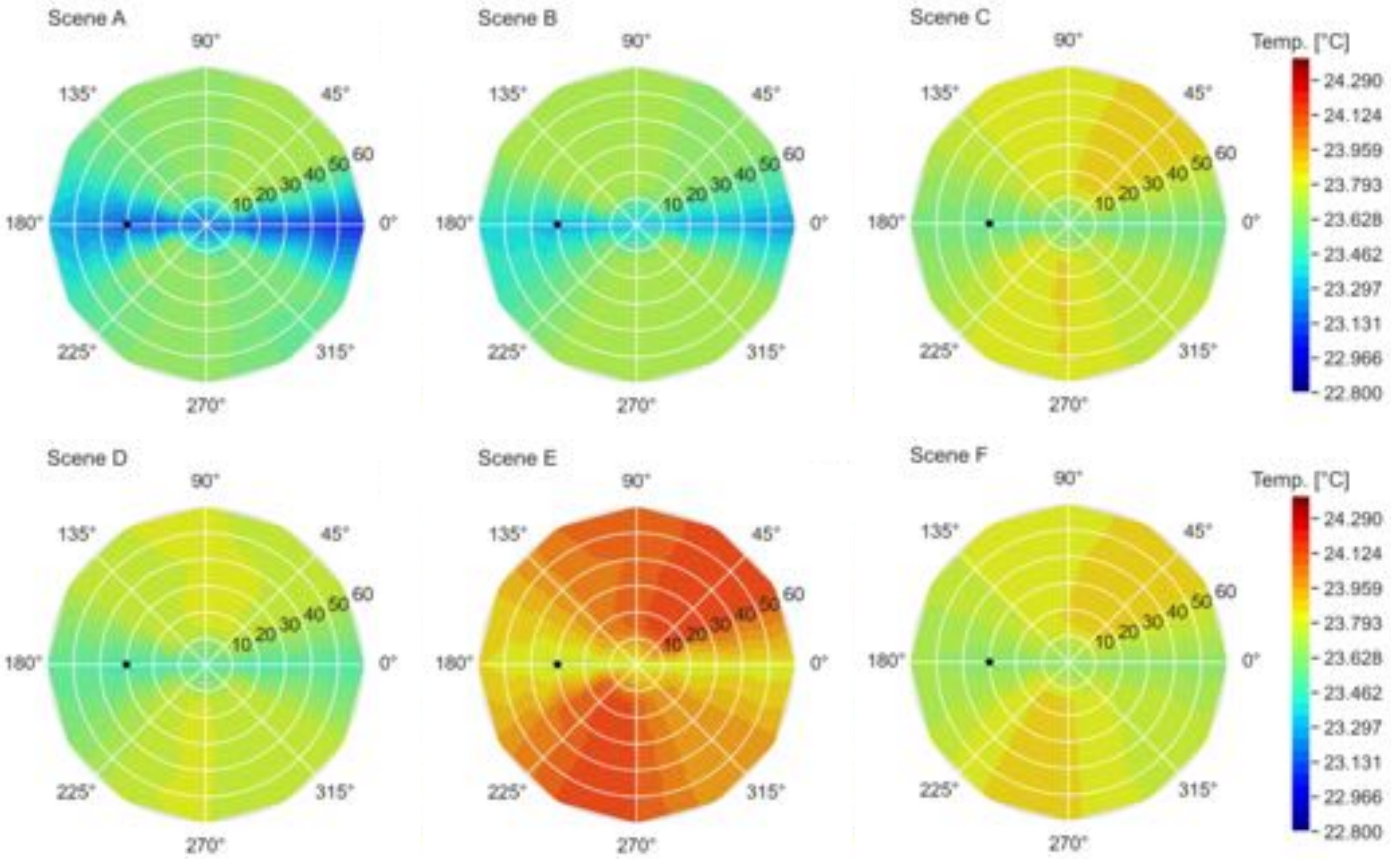
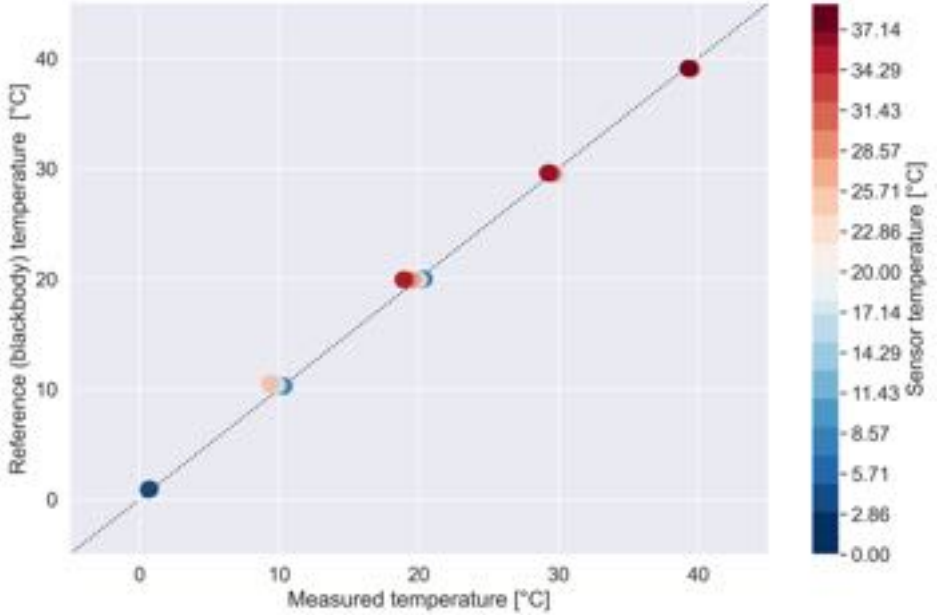
Sensor temperature ... ?



Clear increase in temperature of the sensor at certain angles…

→ Sensor inter-comparison
→ Calibration at PMOD/WRC can help characterise this…



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Take home messages

Goniometer measurements: now fully set-up for thermal directionality experiments

- Other thermal instruments and targets could be tested, open for collaboration…

Forest directionality :

- Initial results on structure only forests seem sensible, caution needed for sensor temperature
- Upcoming: structure + plant physiology, plus other factors (gap fraction, component emissivity, fractional coverage)

Extrapolation to satellite and ”real” data: putting laboratory conclusions in the context of real data

- Airborne (TASI) and UAV data acquired
- Application / testing of existing BDTF kernels
- Thermal instrumentation at two forest sites in progress

Thank you!

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https://www.geo.uzh.ch/en/units/rs/research/TIRLab.html

For more info about the T-SEC project and different ecosystems, see two posters:

Thermal remote sensing of Swiss inland waters: Instrumentation and preliminary results from three pre- and high-alpine lakes • **Abolfazl Irani Rahaghi**

Multi-scale thermal infrared remote sensing to monitor land surface temperatures over Murtèl rock glacier, Switzerland • **Kathrin Naegeli**