Anisotropy corrections for thermal infrared satellite imaging

An ESA-VITO co-funded research

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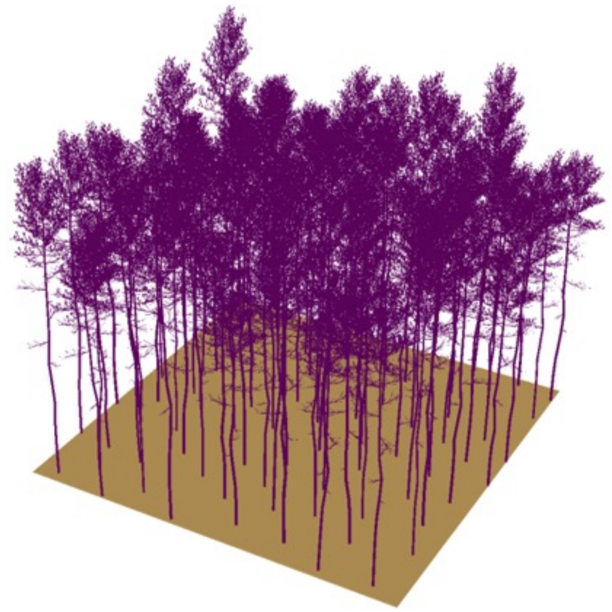
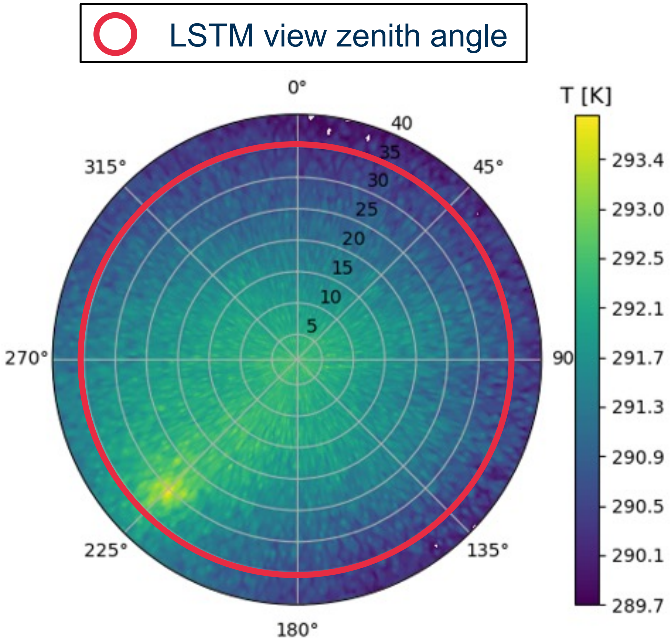
Problem statement: LST $= f(\text{sun}-\text{sensor geometry})$

Directional anisotropy effects

ΔT up to 16°C (Kimes & Kirchner, 1983)



Forest generated with DART (CESBIO).



Directional brightness temperature.

→ directional correction

SwathSense 2021

An airborne campaign

- Joint NASA-ESA; King's College London led airborne campaign
- Investigate directional effects for LSTM
  - **LST**
  - Surface reflectance
- UK
- **Spain (LIAISE)**
  - **Airborne measurements**:
    - CASI-1500, SASI 600
    - **TASI-600** (thermal imager)
      - FOV 40°
      - 4-m resolution
      - 32 bands (8-11.5 µm)
  - Ground measurements

Data set

LIAISE

Multiple days		
19/07/2021	22/07/2021	24/07/2021

Multiple directions		
Solar principal plane	⊥ solar principal plane	Sentinel-2/LSTM orbit

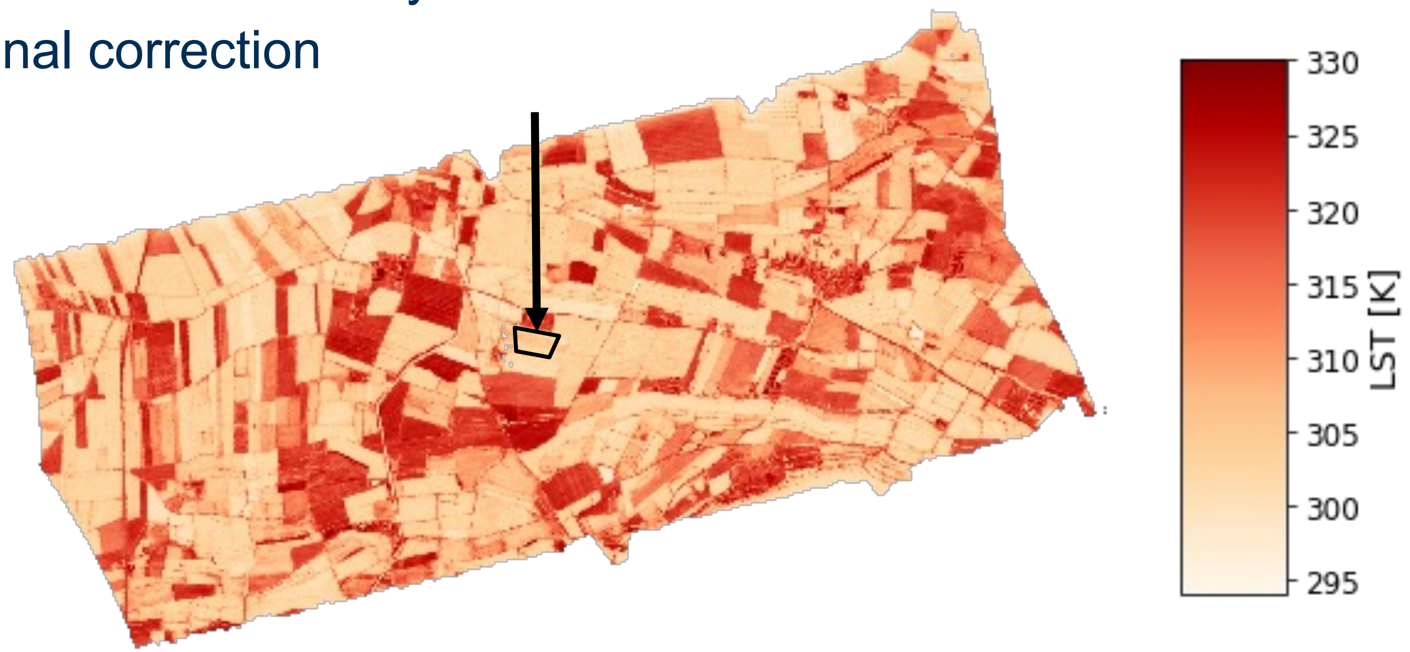
Up to seven parallel flight lines (~ viewing zenith angle)						
-18°	-12°	-6°	0°	6°	12°	18°

Crop fields
Alfalfa reference field

Flight plan for solar principal plane and ⊥ solar principal plane.

Strategy

- Select field: Alfalfa
- Collect measurements (19, 22 & 24/07)
- Apply temporal correction
- Training data (19 & 22/07): construct directionality model
- Test data (24/07): apply directional correction



LIAISE flight line perpendicular to the solar principal plane.

Temporal correction

24/07/21

- Reference temperature

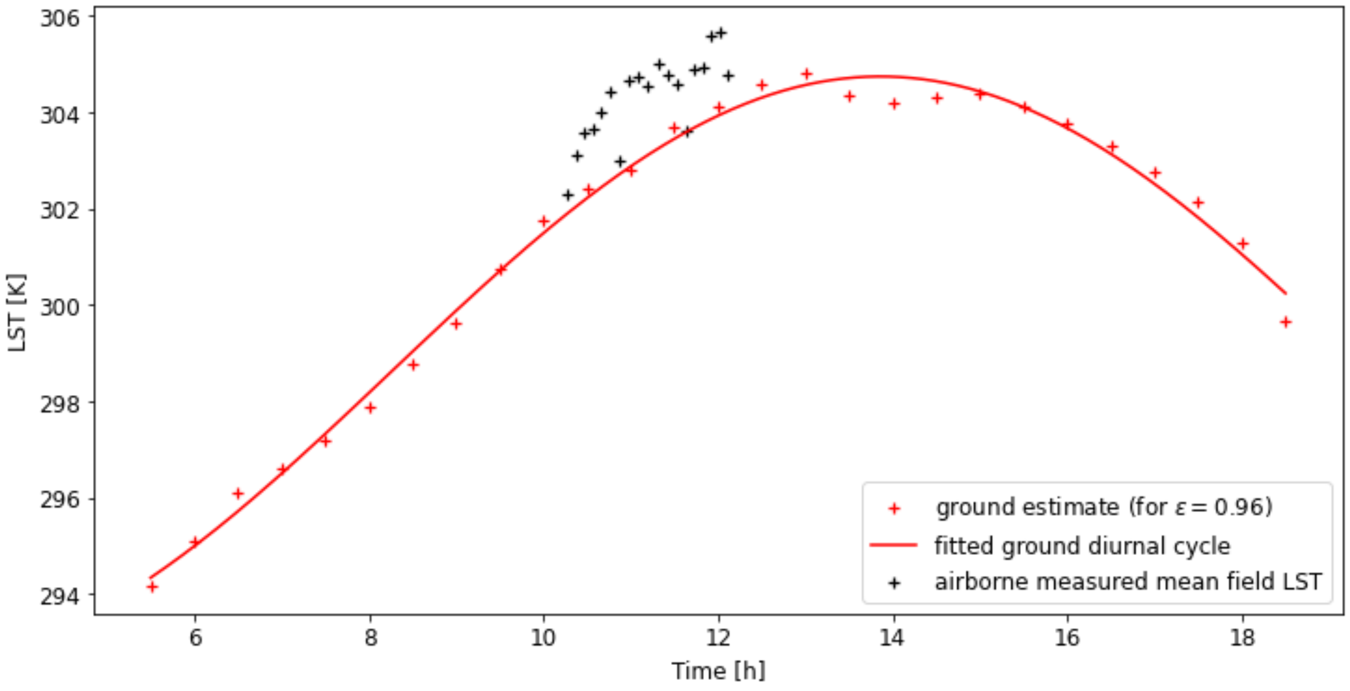
$$T_{ref} = \max\left(T_{diurnal}(t)\right)$$

- Correction factor from diurnal cycle

$$k_{correction}(t) = \frac{T_{ref}}{T_{diurnal}(t)}$$

- Temporal correction of airborne LST

$$LST_{corrected}(t) = k_{correction}(t) \cdot LST(t)$$



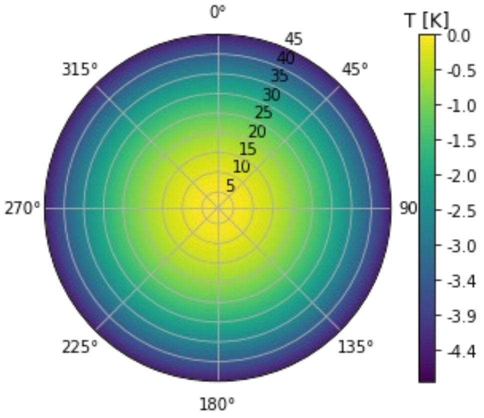
Airborne and ground measurements.

Parametric models

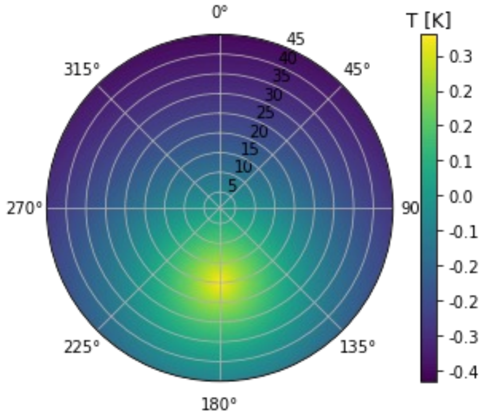
A general framework for kernel-driven thermal radiation directionality (Cao et al., 2021)

$$T(\theta_v, \theta_s, \Delta\phi) = f_{iso} + f_{base\ shape} \cdot K_{base\ shape}(\theta_v) + f_{hotspot} \cdot K_{hotspot}(\theta_v, \theta_s, \Delta\phi)$$

$$T(\theta_v, \theta_s, \Delta\phi) = f_{iso} + f_{base\ shape} \cdot$$



$$+ f_{hotspot} \cdot$$

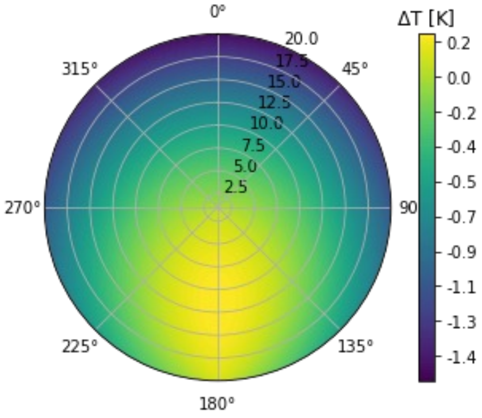


$\theta_s = 20°, \phi_s = 180°.$

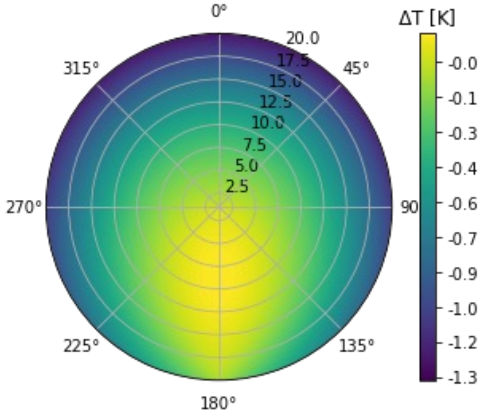
→ coefficient estimation based on observations

Parametric models

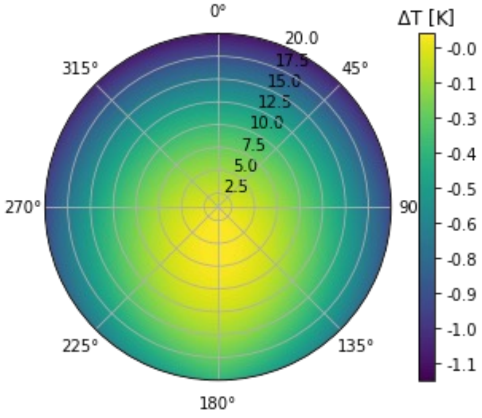
Training set: 19th July and 22nd July



a. Vinnikov-RL (Cao et al., 2021)



b. LSF-Chen (Cao et al., 2021)

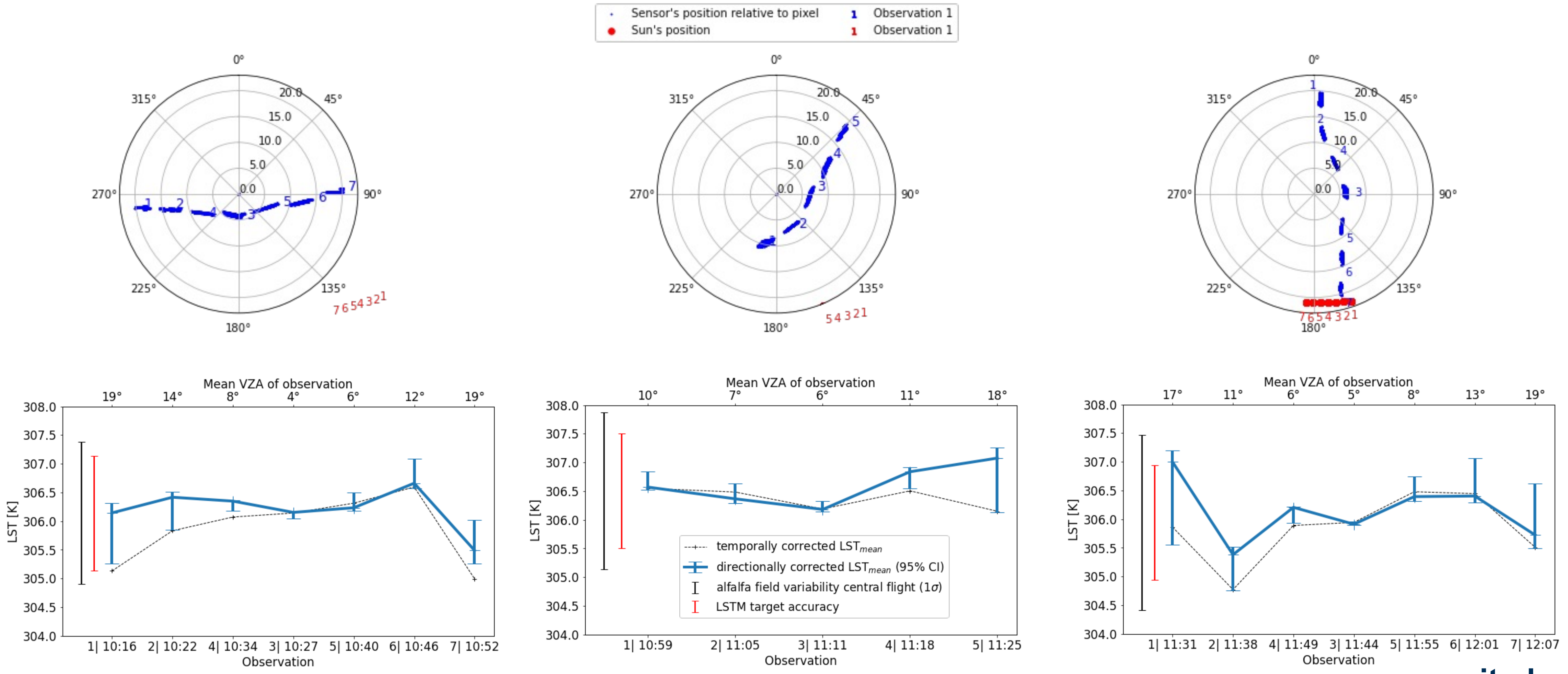


c. GO3 (Liu et al., 2020)

The Sun is positioned at a 180° azimuth and a 20° zenith angle.

Directional correction (Vinnikov-RL)

Test set 24th July



a. Sentinel-2 orbit *b. Solar principal plane* *c. ⊥ solar principal plane*

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Challenges

Limited directional effects

- Small zenith angles
- No “pure” hotspot

High uncertainty in hotspot parameters

- Few LST measurements
- “Pure” hotspot configuration exceptional
- Practical issue

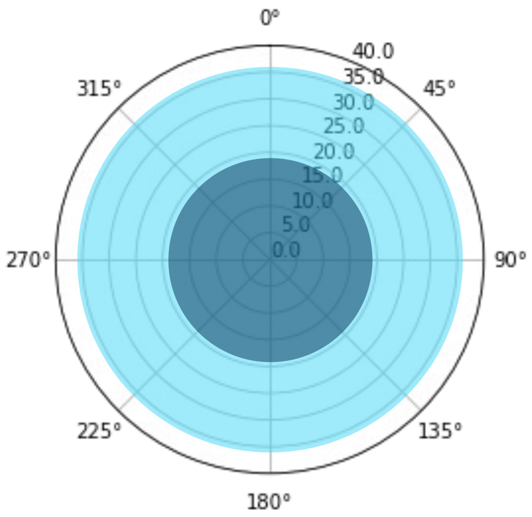
No significant parametric model outperformance

- See above

What’s next?

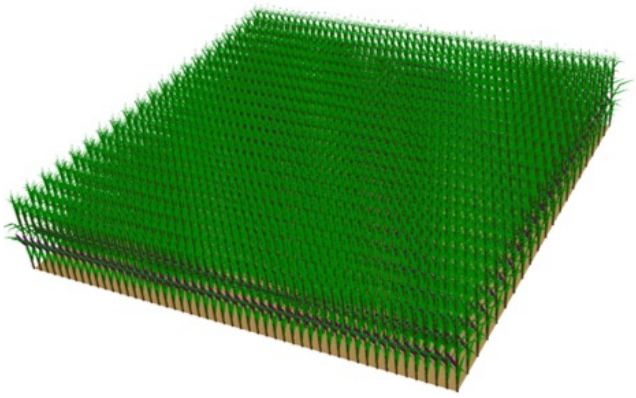
SwathSense 2023

- Zenith angles up to 36°



Sampling regions SwathSense campaigns.

- Field geometry



DART row-planted crop field.

Thank you

More questions?

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