# *Exploring Forest-Atmosphere Interactions Under Heat Extremes in a Semi-Arid Region*

**Yotam Menachem,** Leehi Magaritz-Ronen, Eyal Rotenberg, Lior Hochman, Shira Raveh-Rubin and Dan Yakir
Department of Earth and Planetary Sciences, Weizmann Institute of Science, Rehovot, Israel
yotam.menachem@weizmann.ac.il

## *Research Aim*

(1) Explore feedback on boundary layer (BL) dynamics and local weather under different synoptic heat waves, above a semi-arid forest. (2) Evaluate the implications of afforestation in different scale configurations.

## *Semi-Arid Forest Drives Enhanced Surface-Atmosphere Sensible Heat Fluxes and Boundary Layer Dynamics*

The low albedo of the semi-arid Yatir forest compared to the surrounding shrubland results in large midday sensible heat flux (H) (Figs. 1c, 2). Combined with low aerodynamic resistance, it can initiate secondary circulation within the BL. On larger scales, it can affect the local weather systems (Stern et al., 2023; Eder et al., 2015).

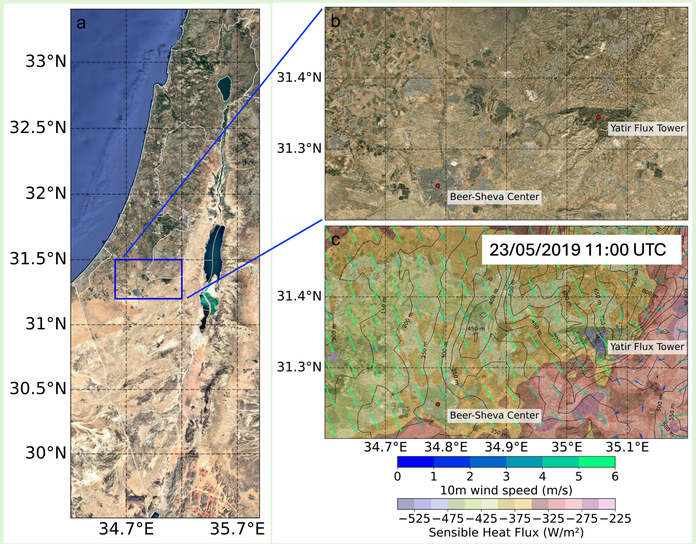


**Fig. 1** Location of the Yatir forest (a), its surrounding desert (b), and ICON simulated sensible heat fluxes during a high-pressure associated heat wave (c). Black contours, and arrows indicate topography and 10m wind speed and direction.

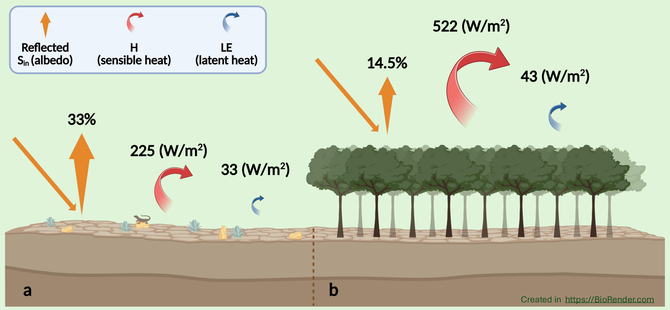


**Fig. 2** Yatir forest and the surrounding desert fluxes during summer midday. The size of the arrows represents the magnitude, with straight and round arrows for radiative and non radiative fluxes, respectively.

## *Synoptic Patterns Shape Forest–Atmosphere Exchange*

In spring (Fig. 3), local heat waves are driven by hot-air advection or subsidence under high-pressure systems. Synoptic forcing varies across events, resulting in different H anomalies at Yatir. 188 heat waves have been identified since 2011, using Tatarinov et al. (2015). Events with the strongest anomalies were selected as case studies.

| | Red Sea Trough | Cyprus Low | Sharav Low | Persian Trough | High Pressure system |
|---|---|---|---|---|---|
| JAN | 0 | 2 | 0 | 0 | 2 |
| FEB | 0 | 1 | 1 | 0 | 2 |
| MAR | 9 | 5 | 3 | 0 | 6 |
| APR | 12 | 4 | 7 | 3 | 14 |
| MAY | 10 | 2 | 4 | 17 | 11 |
| JUN | 0 | 0 | 7 | 10 | 9 |
| JUL | 0 | 3 | 0 | 2 | 0 |
| AUG | 0 | 0 | 0 | 1 | 1 |
| SEP | 1 | 0 | 1 | 5 | 3 |
| OCT | 6 | 0 | 1 | 1 | 4 |
| NOV | 6 | 0 | 0 | 0 | 5 |
| DEC | 5 | 1 | 0 | 0 | 1 |

**Fig. 3** Heatmap showing the number of heat waves attributed to each of the five synoptic groups using Alpert et al., 2004 synoptic classification. Red Sea Trough, Cyprus Low, Sharav Low are typically associated with advection-driven heat waves, while Persian Trough, and Upper-level High-pressure system are linked to subsidence-induced heat waves.

## *Calibrated, Validated, and Scaled-Up Yatir Forest in ICON*

- Control (1.25 km nested grid): IMS operational land surface properties further calibrated using in-situ flux tower data and previous studies
- Validation of 2-m temperature and H against Yatir flux tower measurements (Fig. 1c, Fig. 5)
- Afforestation experiment: categories 4, 6 in the green rectangle replaced by 'Yatir' categories (2, 3) (Fig. 4)

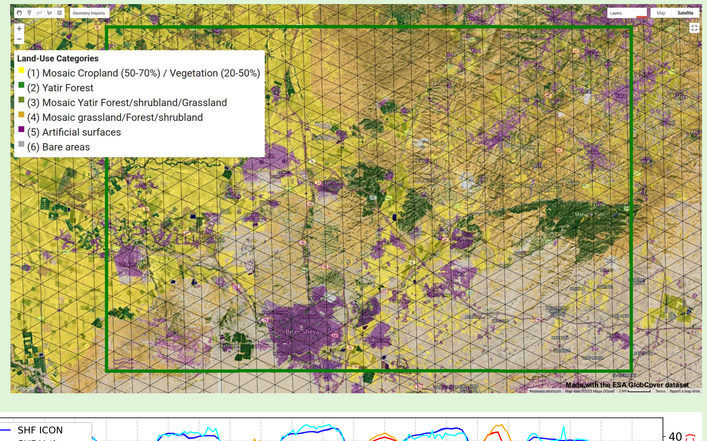


**Fig. 4** Land-use categories and model grid over the northern Negev region. The green polygon outlines the afforested domain used in the numerical experiment. The overlaid grid shows part of the 1.25 km nested simulation domain. Land cover is based on a modified EXTPAR file.


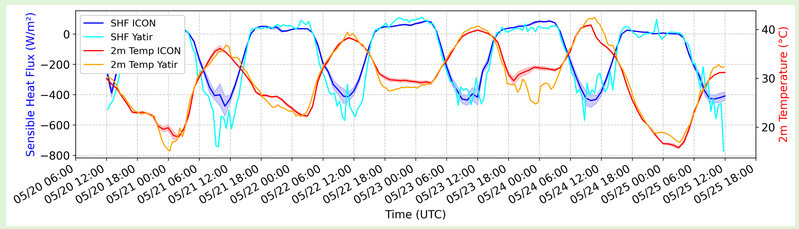


**Fig. 5** Validation of ICON control simulation of high-pressure system event (21–25 May 2019) against in-situ measurements.

## *Afforestation Enhances Surface H Fluxes and Triggers Local Circulation*

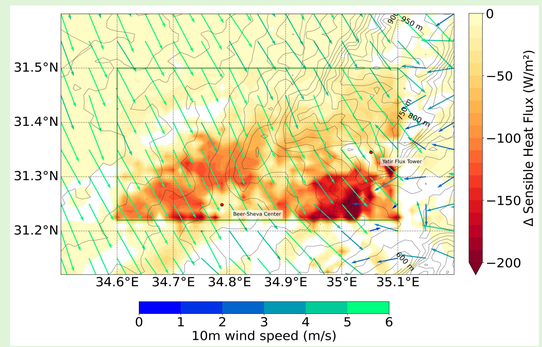


**Fig. 6** Difference in surface H due to afforestation on 21 May 2019 at 11:00 UTC. The afforested domain is outlined in green.

A numerical experiment to assess the biophysical impact of afforestation after land surface properties adjustment to local forest cover (Fig. 4) shows a strong increase in H (exceeding 200 W/m² near 35.02°E) (Fig.6) and changes in near-surface wind patterns (compared to the control; Fig. 1c). Localized feedback between land cover change and BL dynamics are clearly indicated.




**Fig. 7** Vertical cross-section at latitude 31.248° across the afforested domain, showing zonal wind (u, arrows), vertical motion (w, arrows), and air temperature (contours).

The enhanced H fluxes (Fig. 6) result in low-level convergence and strong ascent (~1.5 m/s) near 35.02°E (Fig. 7), accompanied by upper-level divergence, descent on the lee side, and localized secondary circulation. Distorted temperature layers indicate weakened stratification. While thermal forcing dominates, topography may also influence the vertical motion pattern.

## *Conclusions*

**The ICON calibration and its use to simulate large-scale forest cover supported the detection of forest-atmosphere interaction, with stronger effects extending over larger distances**

- Calibration of ICON's land surface data and parameters improved the model representation of the local forest
- Consequently, ICON simulation of expanding forestation captured the large forest-induced increase in sensible heat flux, leading to low-level convergence and vertical motion

## *References*


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