# Secondary circulations above a solitary forest surrounded by semi-arid shrubland

Fabian Eder (1,2), Frederik de Roo (1), Eyal Rotenberg (3), Dan Yakir (3), Hans Peter Schmid (1), Matthias Mauder (1,2)

*(1) Institute of Meteorology and Climate Research, Atmospheric Environmental Research (IMK-IFU), Karlsruhe Institute of Technology (KIT), Kreuzeckbahnstrasse 19, 82467 Garmisch-Partenkirchen, Germany*
*(2) Environmental Sciences and Energy Research (ESER), The Weizmann Institute of Science, Rehovot 76100, Israel*
*(3) Institute of Geography and Geoecology (IfGG), Karlsruhe Institute of Technology (KIT), Kaiserstraße 12, 76131 Karlsruhe, Germany*

**Contact:** fabian.eder@kit.edu

## The Yatir site

- forest dominated by *Pinus halepensis*, planted mostly from 1964 to 1969
- size: 2800 ha, approx. a triangle, with 10 km in East-West direction and 6 km in North-South direction
- mean annual precip.: **285 mm**

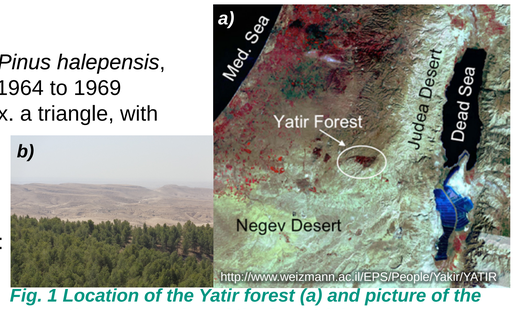


*Fig. 1 Location of the Yatir forest (a) and picture of the south-western edge of the forest (b)*

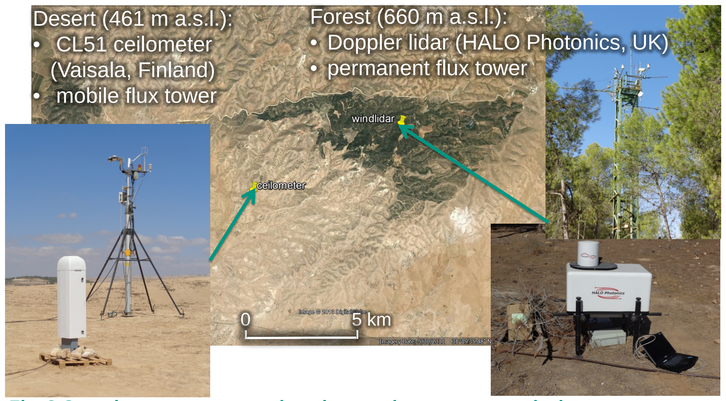


*Fig. 2 Overview: measurement locations and measurement devices*

## Research question

The 'canopy convector effect' *(Rotenberg and Yakir 2010, 2011)*:
**sensible heat fluxes are higher above the forest** than above the desert
→ Does a **secondary circulation** develop between desert and forest ?

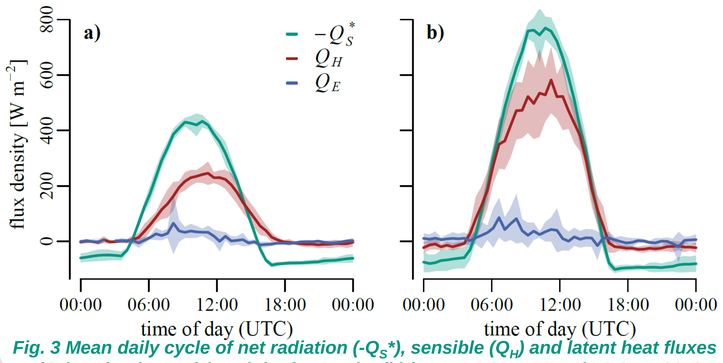


*Fig. 3 Mean daily cycle of net radiation ($-Q_S$*), sensible ($Q_H$) and latent heat fluxes ($Q_E$) at the desert (a) and the forest site (b) between 21 Aug and 10 Sept 2013*

## Secondary circulation between forest and desert

**Hypothesis**: Higher surface buoyancy (220 - 290 W m$^{-2}$) above the forest should induce a **persistent vertical updraft** (Fig. 4)

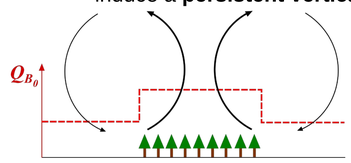


*Fig. 4 Idealized scheme illustrating how the increased surface buoyancy flux ($Q_{B0}$) above the forest induces a secondary circulation*

**Doppler lidar measurements:**

A **persistent vertical updraft** , i.e.
- mean vertical wind > 0.5 m s$^{-1}$
- for at least 3 h period
- extending > 500 m in height,

was found **on 5 of the 16 measurement days**, e.g. on 10 Sept 2013 (Fig. 5).

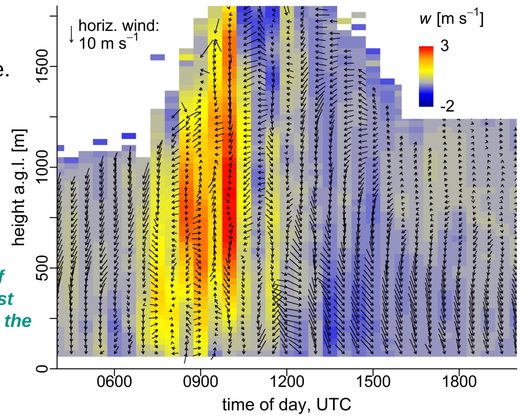


*Fig. 5 Doppler lidar measurements of the wind field above the Yatir forest on 10 Sept 2013; the arrows show the horizontal wind speed and wind direction, the colours indicate the vertical wind component*

**Why no persistent vertical updraft on every day?**
A simple large-eddy simulation of the Yatir area (Fig. 6) showed that, under ambient background wind (6 m s$^{-1}$), the strongest effect on the vertical wind speed should appear **approx. 5 km downwind** from the forest centre.
To date, it is not clear, why we found a persistent updraft on those 5 days. This needs further investigation.

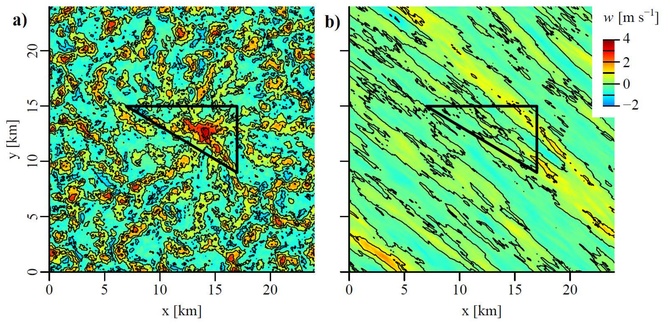


*Fig. 6 Large-eddy simulation of the 30-min mean of the vertical wind component at 0.6 $z_i$ for zero background wind (a) and a background wind of 6 m s$^{-1}$ (b); the difference between forest and desert was encoded in different surface fluxes and roughness lengths and topography was neglected; the thick black lines indicate the location of the forest in the model domain*

## Implications for eddy-covariance measurements (the energy balance closure problem)

**Hypothesis**: The presence of meso-scale circulations should increase the **non-closure of the energy balance** in the area

The surface-layer wind spectra (Fig. 7) showed that low-frequency contributions can be found in the **horizontal wind components**. Above the forest, the low-frequency motions are broken up into smaller eddies (Fig.7c,d).

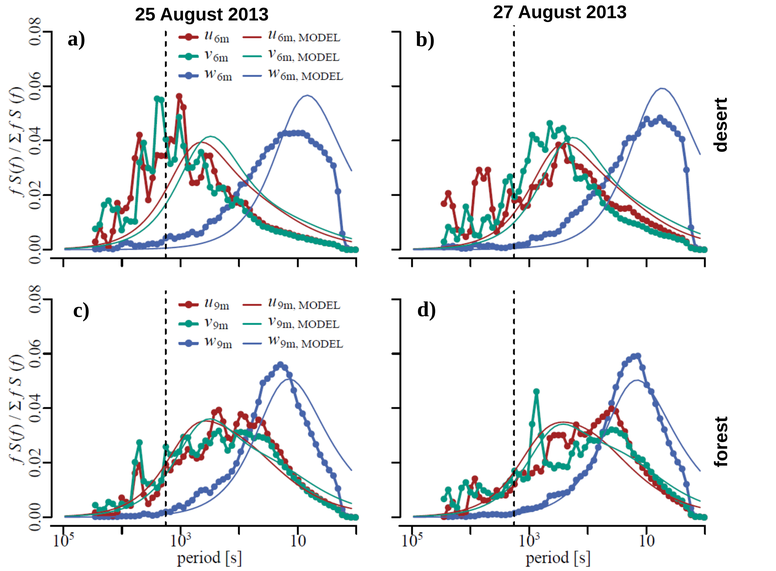


*Fig. 7 Normalized wavelet spectra of the three wind components u, v and w using the sonic anemometer data from (a,c) 25 August and (b,d) 27 August 2013; the upper panel (a,b) shows the data from the desert and the lower panel (c,f) the data from the forest; the surface-layer spectra were compared with the spectral model of Højstrup (1981); the vertical dashed line indicates a period of 30 minutes, which was the averaging time for the eddy-covariance measurements*

The energy balance is **closed at the forest site (*R* = 1.00)**, but it is **not closed at the desert site (*R* = 0.81)**. The low-frequency contributions at the desert site are larger (Fig.7).

$$R = \frac{Q_H + Q_E}{-Q_S^* - Q_G}$$

## Conclusion

***The Yatir forest may induce a secondary circulation which is difficult to capture using a single Doppler lidar. However, low-frequency contributions can be found in the horizontal wind spectra. These contributions are related to the non-closure of the energy balance.***

KIT – University of the State of Baden-Wuerttemberg and
National Research Center of the Helmholtz Association

**Acknowledgements**
The authors would like to thank the staff from the department of Earth and Planetary Sciences of the Weizmann Institute of Science for the assistance during the field campaign.

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