Evaluating multi-year, multi-site data on the energy balance closure of eddy-covariance flux measurements at cropland sites in southwestern Germany

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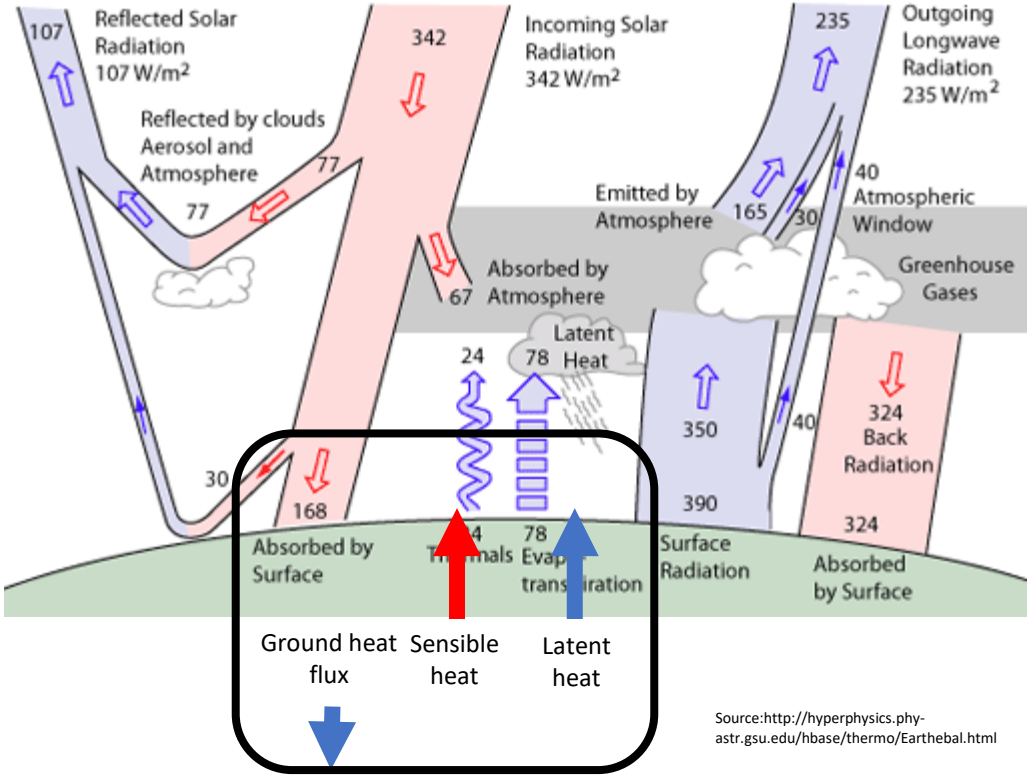
Overall background

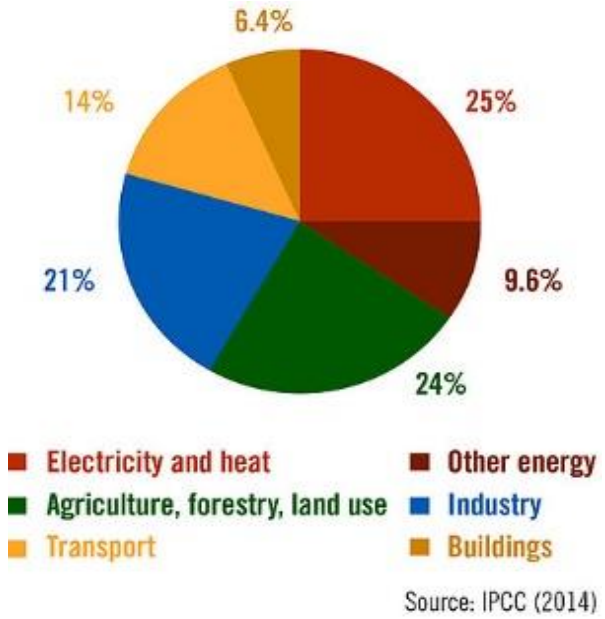
- Different pedo-climatic regions and conditions
- Intensively managed cropland sites under global climate change



Source:http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/Earthebal.html

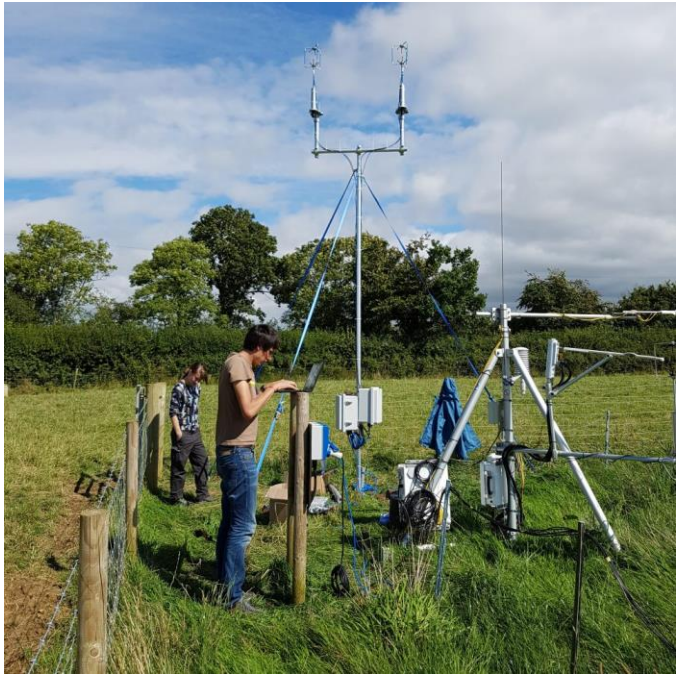
Overall background

- The greenhouse gases (GHG) from agricultural sector
- Problems in precise measurements of carbon, energy, water exchange
- Quantitative dynamics of carbon flux from agricultural ecosystems remain elusive



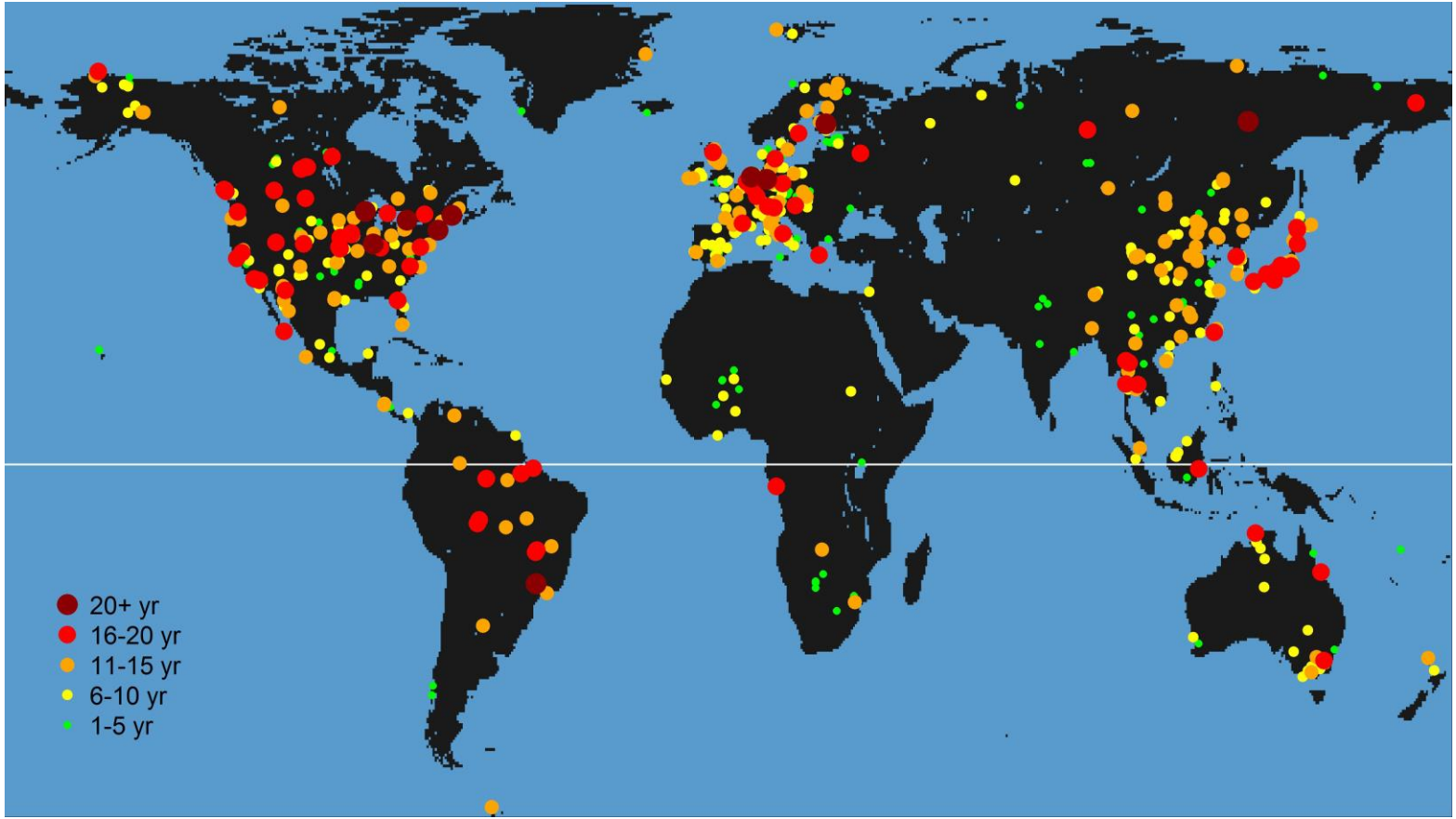
Eddy towers

https://harvardforest.fas.harvard.edu/other-tags/eddy-flux



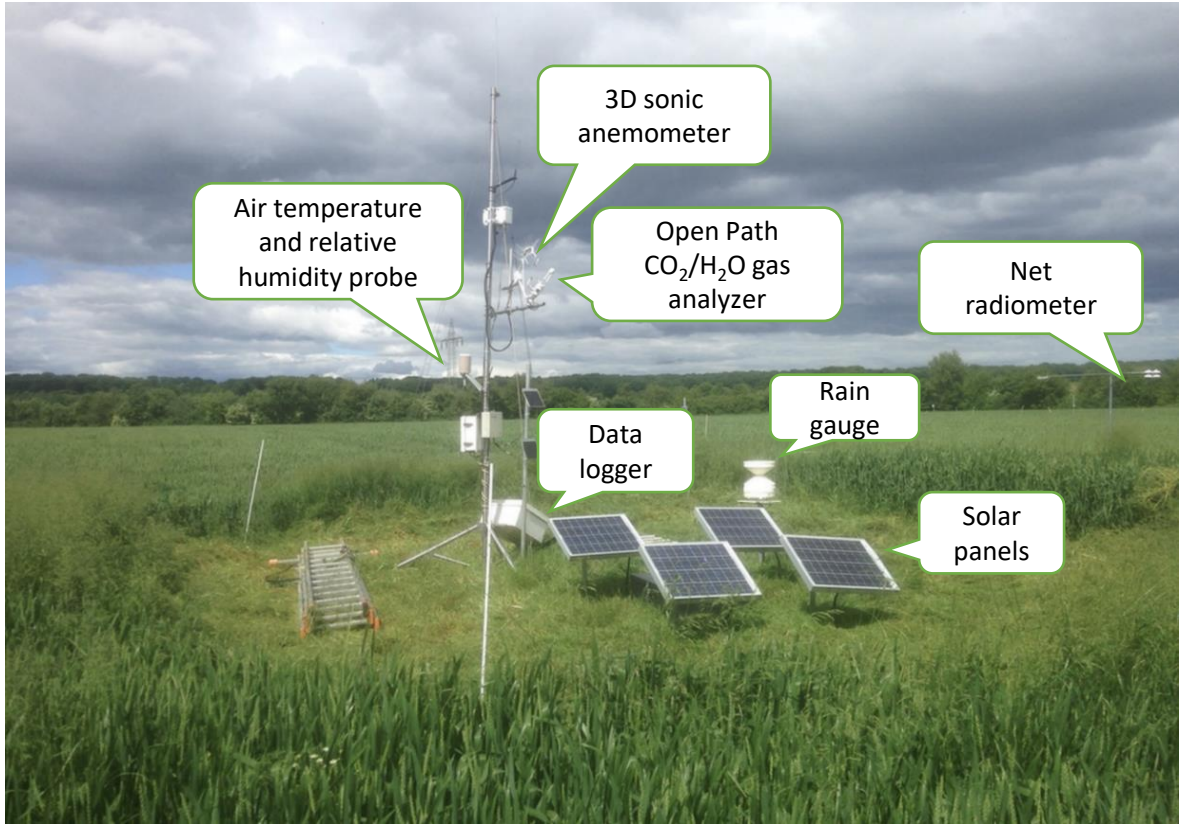
https://blogs.exeter.ac.uk/timhill/2018/12/05/fully-funded-phd-available-developing-and-testing-low-cost-eddy-covariance/

FLUXNET



https://fluxnet.org/sites/site-summary/

Eddy Covariance (EC) method



Source: http://launchtrailermetstation.blogspot.com/2010/08/soil-heat-flux-plate-installation-pics.html

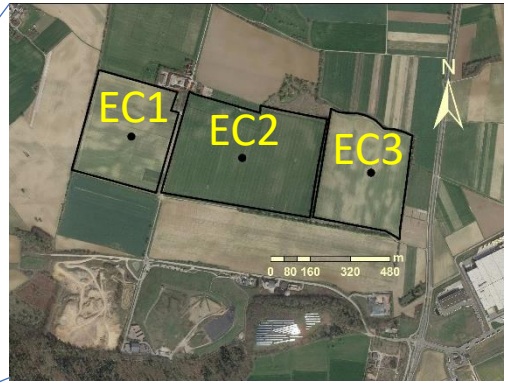
Eddy Covariance method

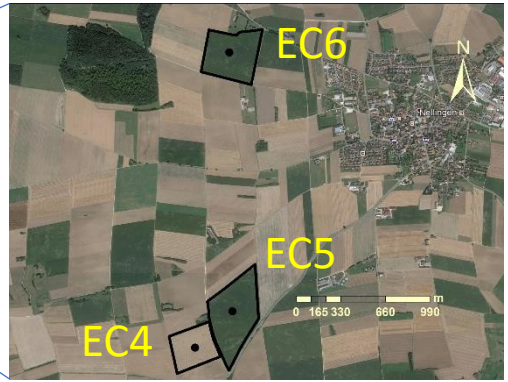
- EC flux data are used to validate land surface models.
- Measured EC fluxes usually do not close the energy balance.
- Energy balance closure ranges from 70 – 90 % for various ecosystems.
- The imbalance of the energy budget has been widely studied.
  - Instrumental errors, uncorrected sensor configurations, problems of heterogeneties in the area, atmospheric conditions, loss of low and/or high frequency contributions to the turbulent fluxes and neglected energy storages

Research aims

To study the causes of the energy imbalance in EC measurements in agricultural croplands

Study area





Kraichgau region

Warm region
Mean temperature: 9.4 °C
Mean precipitation: 890 mm

Swabian Jura region

Colder and harsher climate
Mean temperature: 7.5 °C
Mean precipitation: 1042 mm

Eshonkulov et al. (2019a)

Materials and methods: EBC criteria

Energy balance
(ordinary linear regression)

$$\underbrace{R_n - G}_{\text{Available energy}} = \underbrace{LE + H}_{\text{Turbulent fluxes}}$$

Energy balance ratio (EBR)

$$\frac{H + LE}{R_n - G}$$

Residual energy

$$\text{Res} = Rn - G - H - LE$$

R_n (W m^{-2}) – the net radiation, G (W m^{-2}) – the ground heat flux
H (W m^{-2}) – the sensible heat flux, LE (W m^{-2}) – the latent heat flux

Materials and methods: The energy balance

$$H + LE + S_a + S_q + S_p + S_c = R_n - G$$

Turbulent fluxes

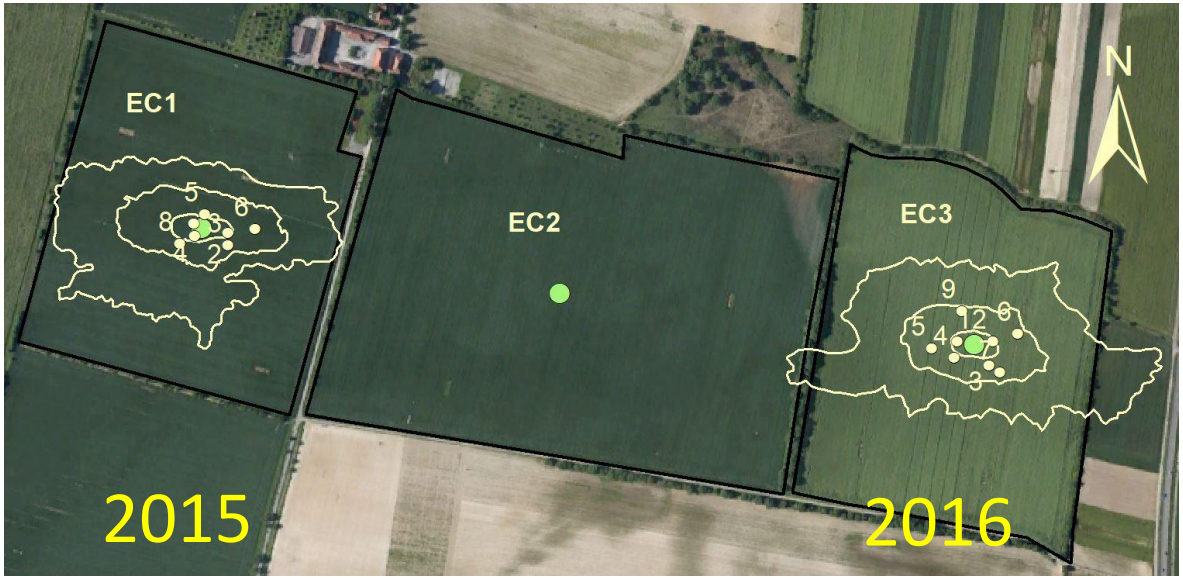
Minor storage terms

Available energy

S_a – air enthalpy change, (W m^{-2})
S_q – atmospheric moisture change, (W m^{-2})
S_p – energy consumption by photosynthesis and release by respiration, (W m^{-2})
S_c – crop enthalpy change, (W m^{-2})

Photo by: Felix Baur

Materials and methods: Footprint



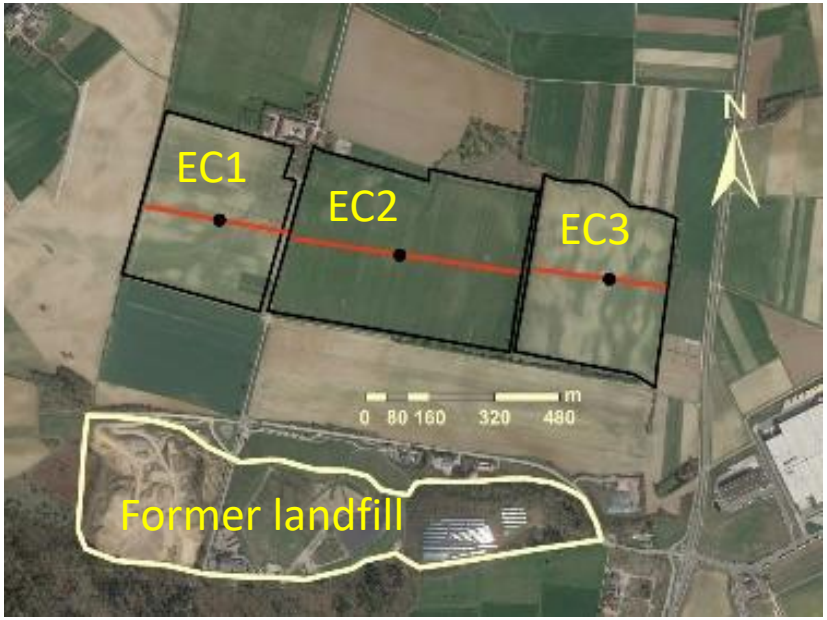
Measurements within footprint:
Soil heat storage (S_g)
Crop enthalpy change (S_c)

Ground heat flux (G): Harmonic method
G_{hp} – harmonic plate
G_{ht} – harmonic temperature
G_{hf} – harmonic temperature (footprint)

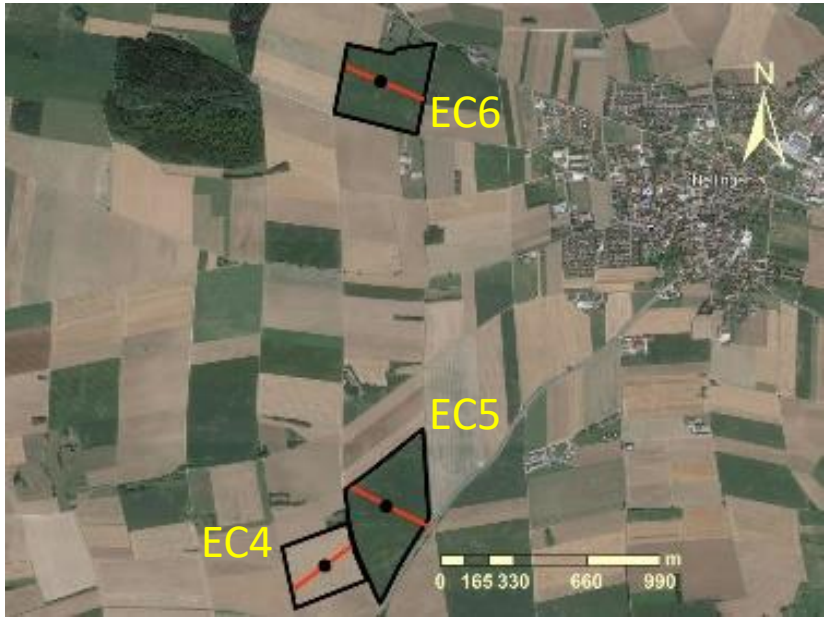
Objective|Hypothesis

Objective	To evaluate if the crop type, site characteristics, wind direction, atmospheric conditions, and footprint area acts as controls on the energy balance closure.
Hypothesis	Multi-year, multi-site observations will provide new insights into the nature of the energy imbalance of EC flux measurements.

Study site

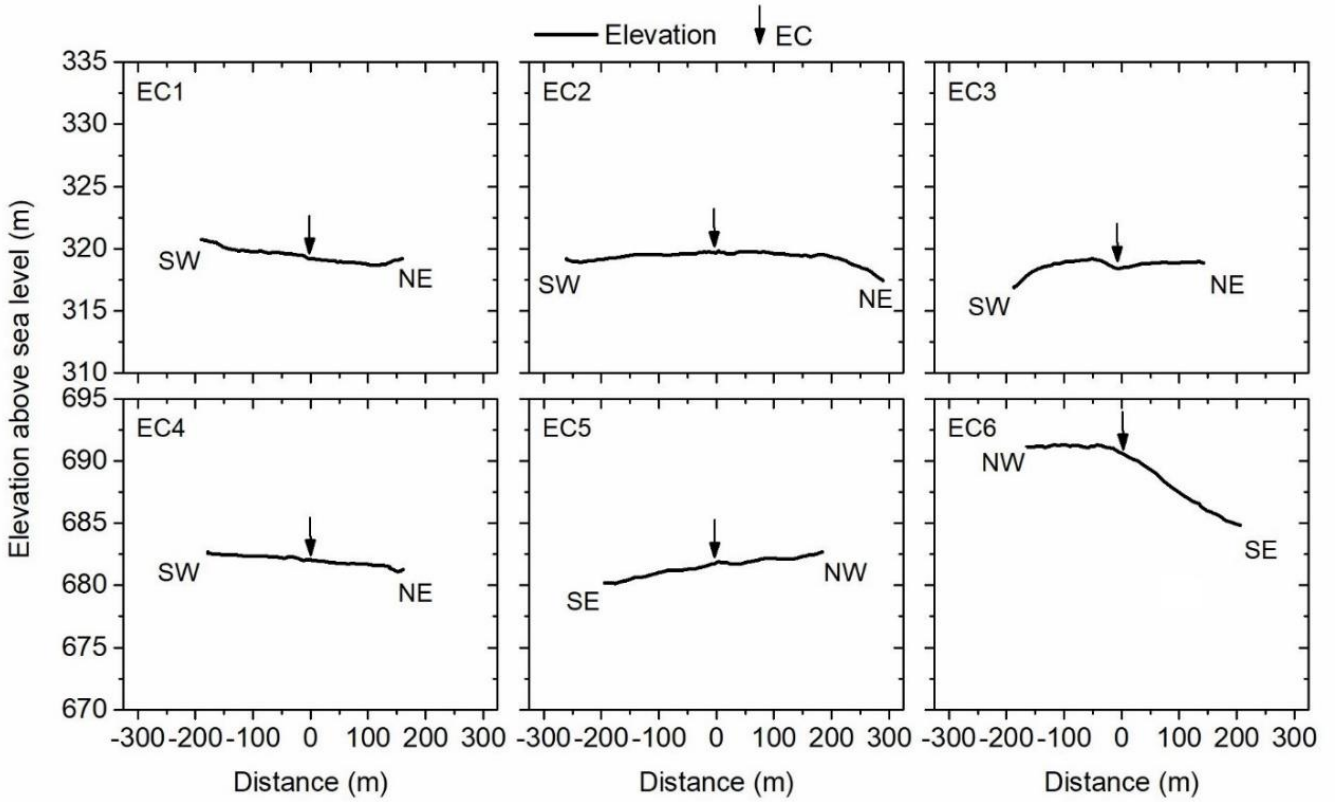


Kraichgau



Swabian Jura

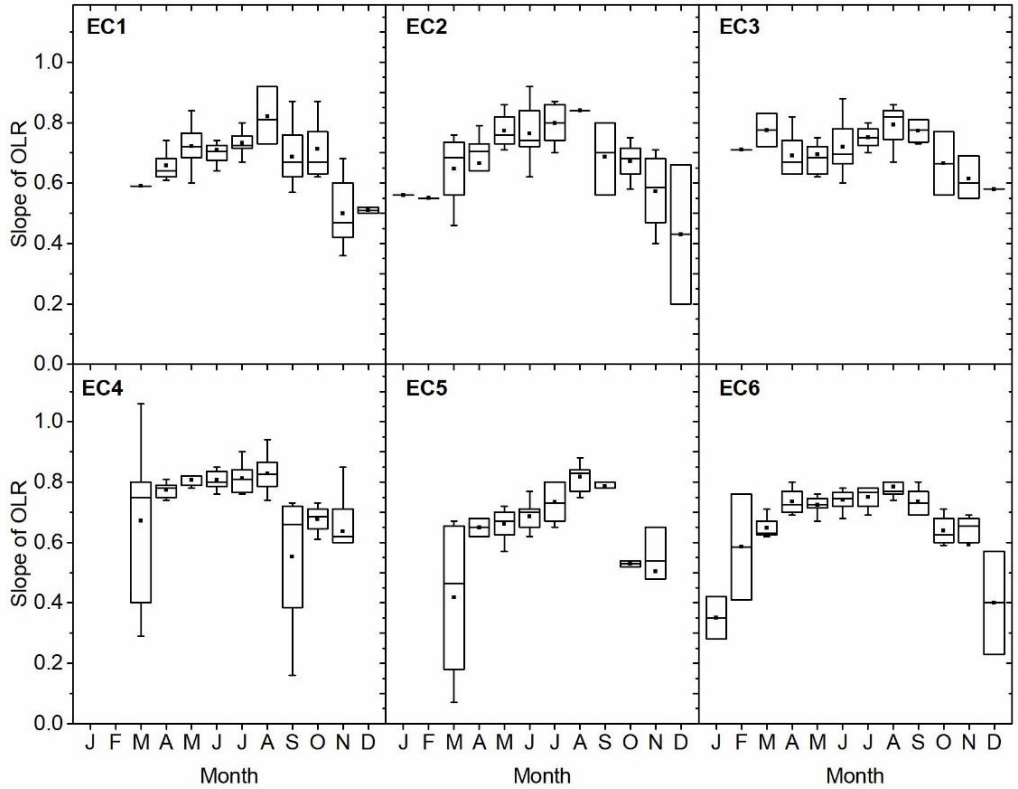
Study site



Kraichgau

Swabian Jura

Monthly averaged EBC by OLR

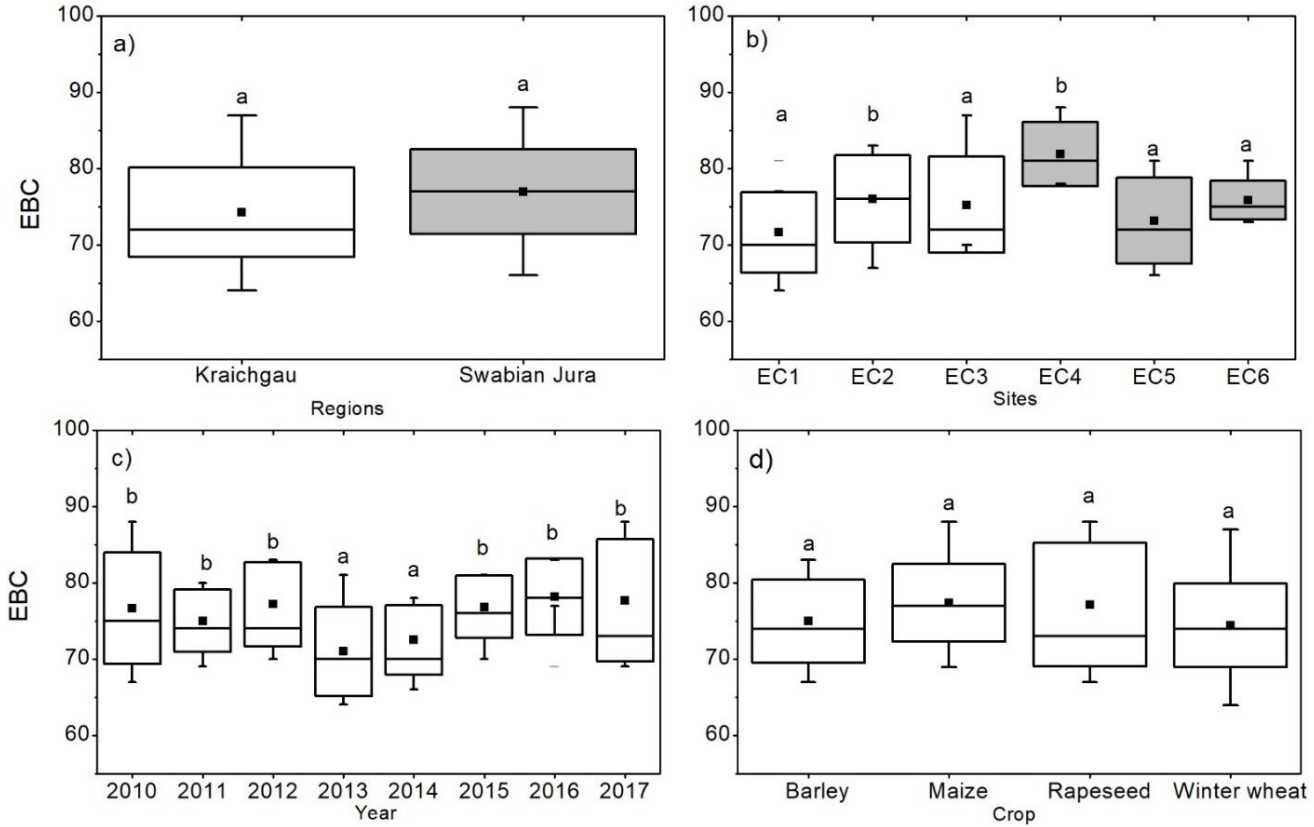


The highest EBC:
July and August

The lowest:
autumn and winter months

Eshonkulov et al. (2019b)

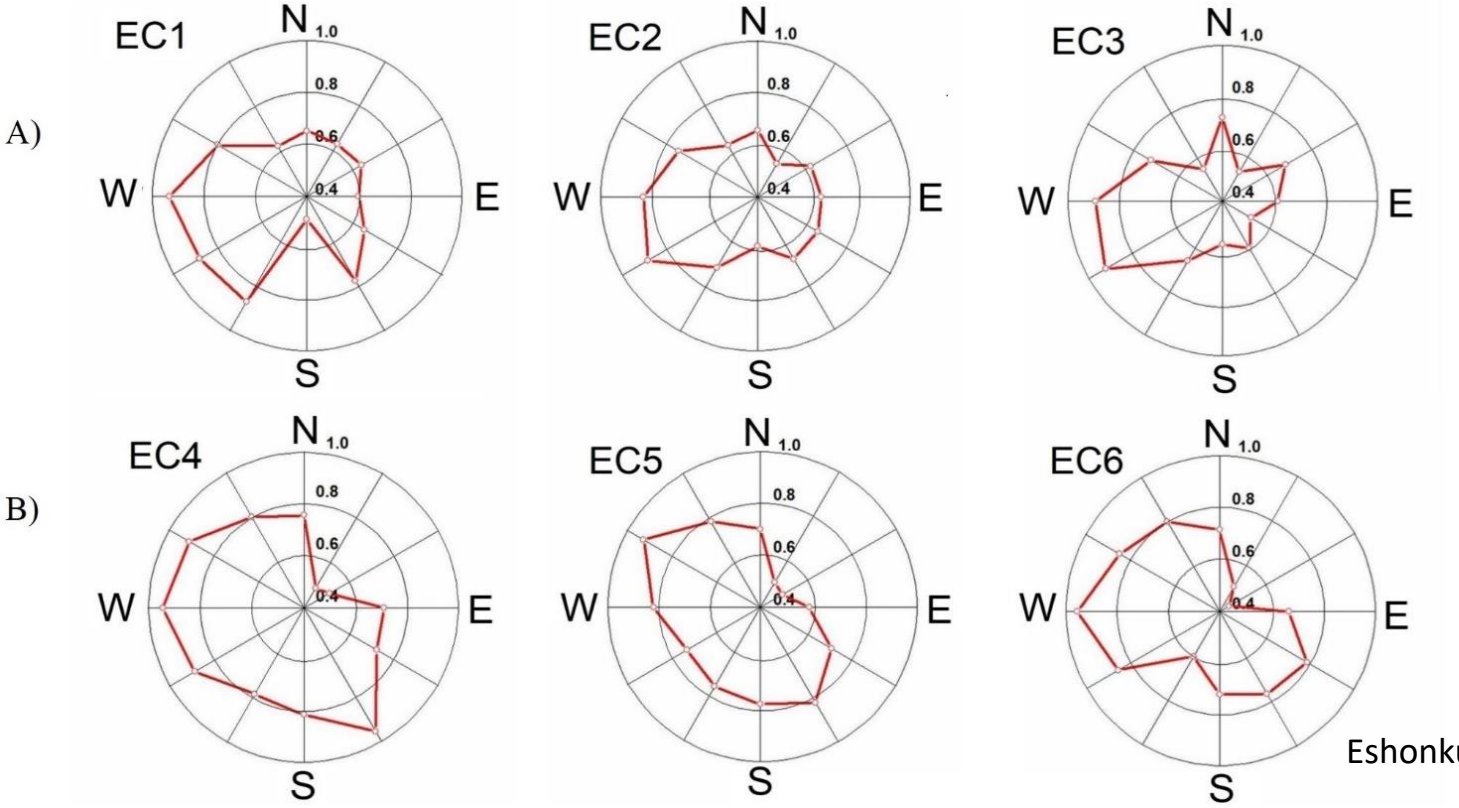
Comparison of EBC



a – insignificant
b - significant

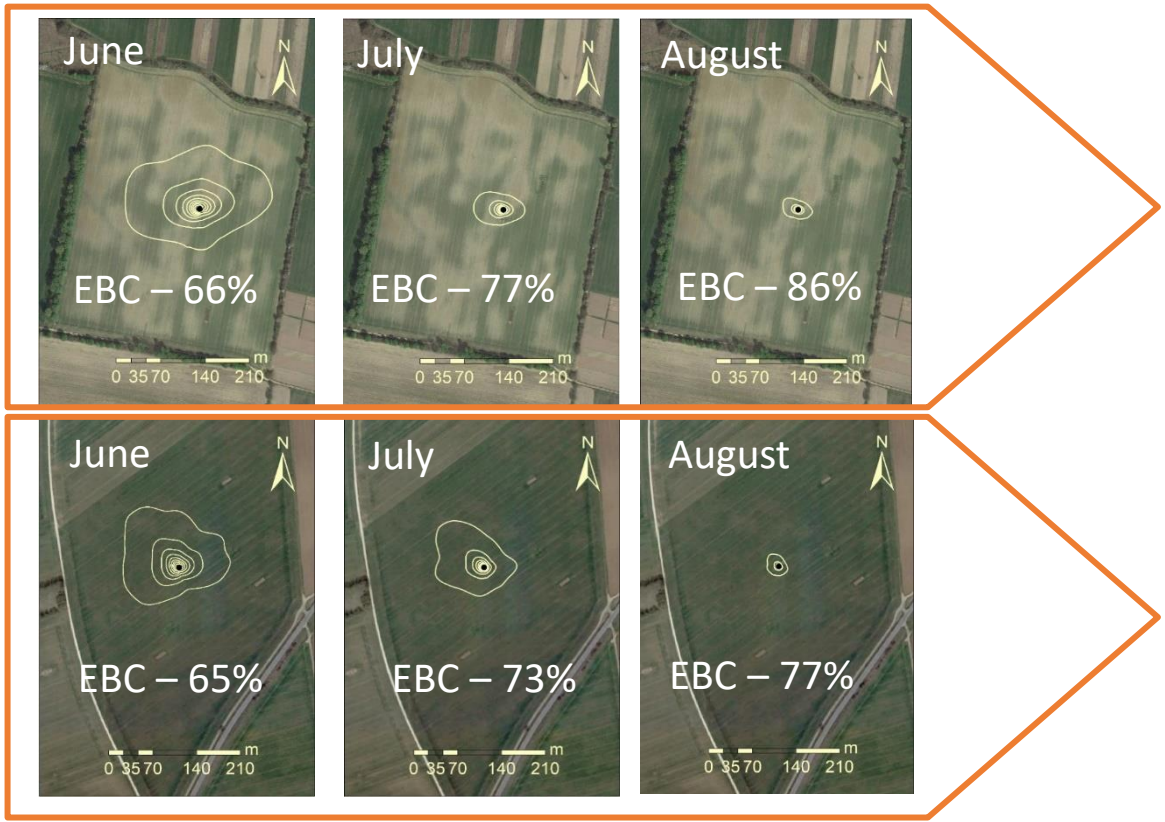
Eshonkulov et al. (2019b)

EBR depending on the wind direction



Eshonkulov et al. (2019b)

EBC depending on footprint size



Conclusions

- The EBC depends on how well thermally and mechanically induced turbulence are developed.
- The EBC was problematic during winter months and under stable atmospheric conditions.
- Furthermore, the EBC was negatively affected by:
  - Heterogeneous source area
  - Flow distortions around the anemometer
- The EBC was positively affected as the footprint area decreased.

Many thanks for your attention