Spatio-temporal patterns of phenological development in Germany in relation to temperature and day length

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Background and Methodology

Introduction

- Phenological development of crops has been extensively studied in field experiments but less so at larger scales for which data availability is often limited.
- The aim of this study was to analyze spatio-temporal patterns of crop phenological development in response to temperature and day length.
- The temperature sum concept derived from field studies and used in many crop models (e.g. McMaster et al., 2008; Ewert et al., 1999) was applied.

Data and methods

- Phenology data of oat (*Avena sativa* L.) recorded at 6019 observation sites were provided by DWD.
- Development stages sowing, emergence, heading, yellow ripeness and harvest and the length of the phases between these stages were analyzed.
- After data filtering for each of 86 eco-regions, 321270 records for the period 1959-2009 were used in the subsequent analysis (Figure 1).

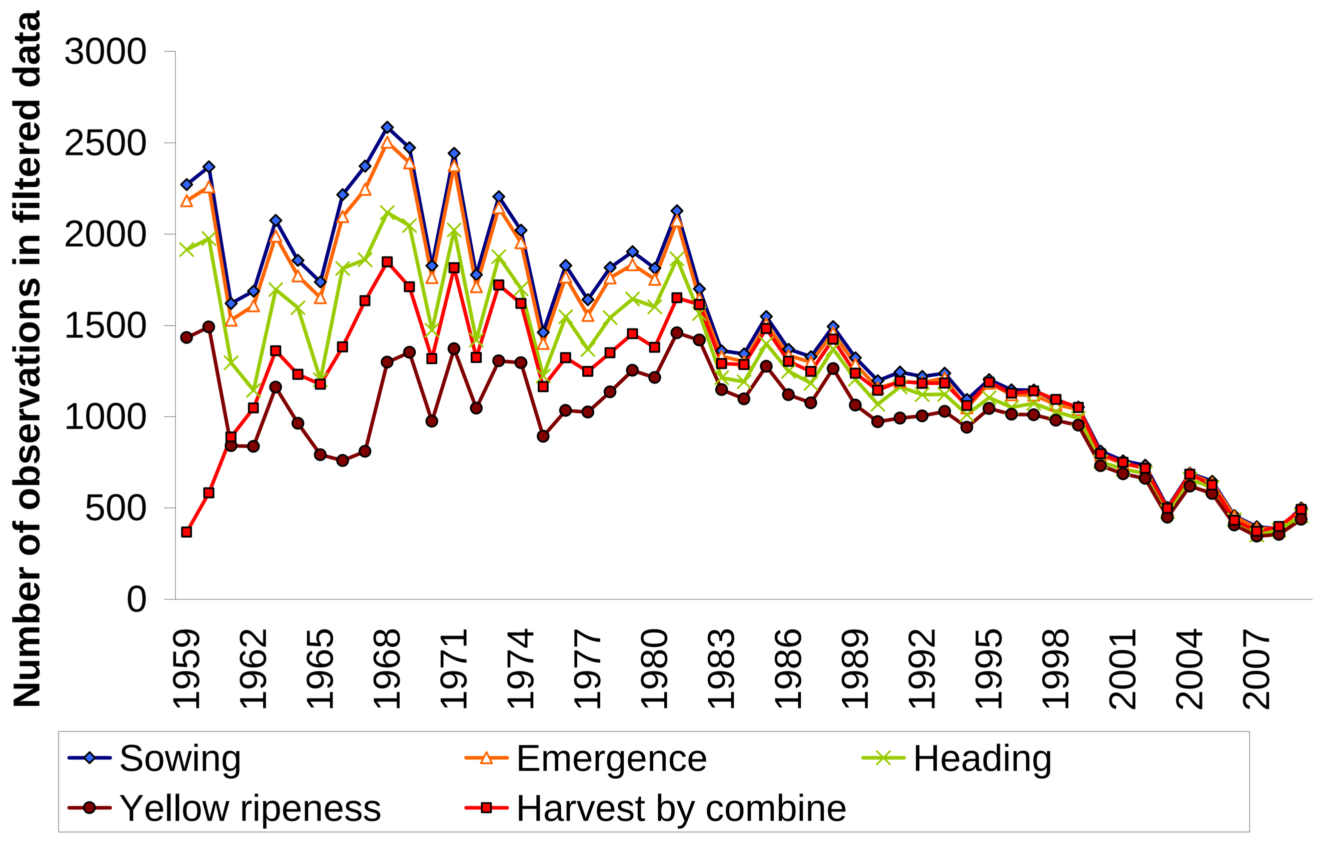

Figure 1. Number of records after data filtering procedure, per phenological stage and year.

- Mean daily temperature at each phenology site was computed from time series of mean monthly temperatures (1 km × 1 km grids) and of mean daily temperature recorded at 1131 weather stations across Germany (Figure 2).
- Trends over time in phenological development were examined by linear regression analysis of the occurrence of phenological stages computed as average of the observations for the whole of Germany.
- The trend analysis was performed for each variable considering observations at sites with at least 30 years of records for the specific variable during the period 1959–2009.
- Spatial patterns were analyzed selecting observations of sites with at least 15 years of records for the examined variable (Figure 2).
- The analysis included computed mean values of timing and duration of phenological stages and phases, respectively and the corresponding mean temperatures, mean day length and mean temperature sum (above 0°C) within the phases per site and per eco-region.

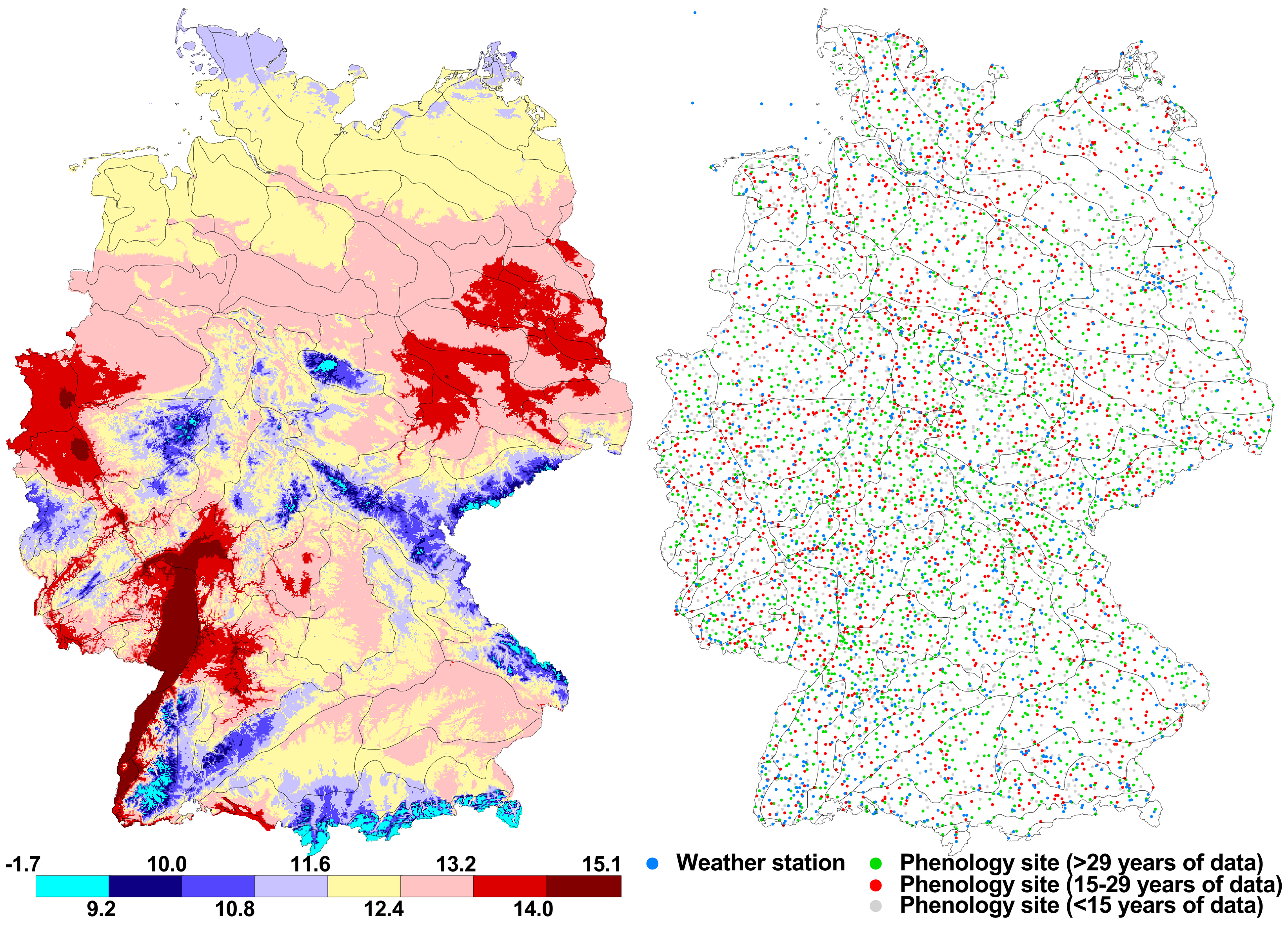

Figure 2. Seasonal (March-August) long-term mean temperature (°C, left) and location of weather stations and phenology sites (right) in German eco-regions.

Results

Spatial patterns in oat phenology

- Distinct spatial pattern in phenological development; differences among eco-regions in stage occurrence and phase length ranging between 15-26 days and 6-21 days depending on the stage and phase, respectively (Figure 3a, 3b).
- Lowest temperature sums for the period from sowing to heading in the hilly eco-regions (below 850 °Cd), largest temperature sums (up to 979 °Cd) in the Rhine valley and in the more continental parts of eastern Germany (Figure 3c).

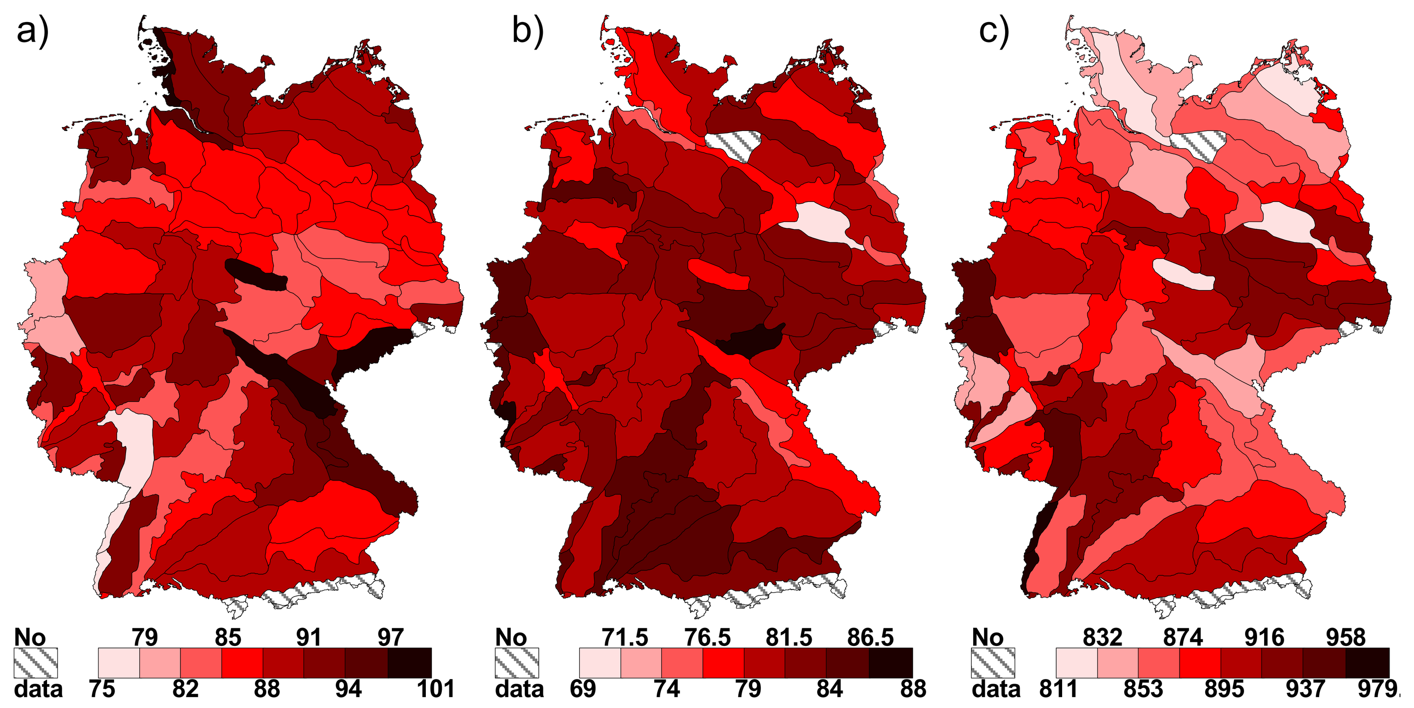

Figure 3. Mean sowing day (day of the year, a), length sowing to heading (days, b) and temperature sum sowing to heading (°Cd, c) per eco-region.

- Spatio-temporal variability was largely explained by effects of temperature and day length (Figure 4).
- Temperature sums and day length corrected temperature sums varied in time and space pointing to the use of different varieties over time and across eco-regions.

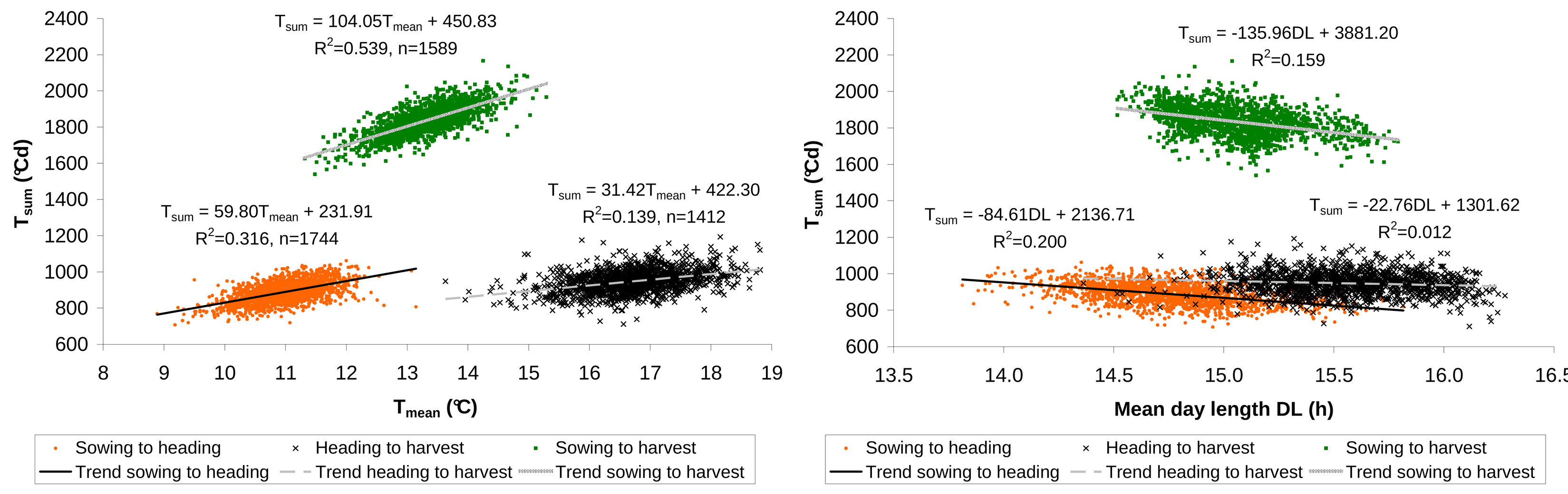

Figure 4. Linear regression of temperature sum T_{sum} on mean temperature T_{mean} (left) and on mean day length DL (right) for station means and the phase sowing to heading.

Change of oat phenology between 1959 and 2009

- Warming trend since 1959 resulted in an earlier onset of all phenological stages and a shortening of most phenological phases (Figure 5).
- Shortening of growing season (1959 and 2009) decreased mean temperature and mean day length due to shift of growing season; resulting reduction in development rate partly compensated for the effect of the warming trend (Figure 5).

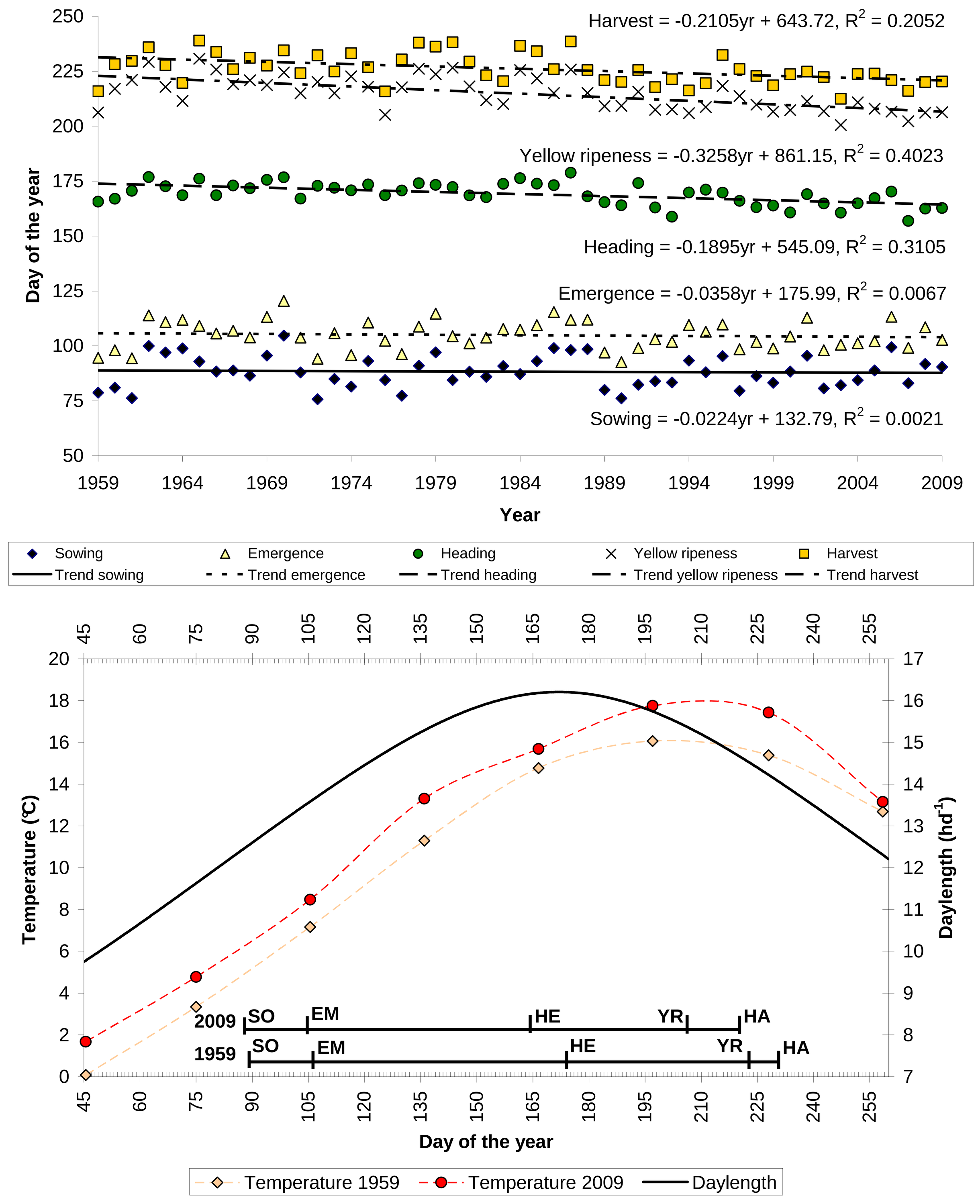

Figure 5. Means across sites of observed sowing, emergence, heading, yellow ripeness and harvest of oat in Germany in the period 1959–2009 (top) and temperature within the oat growing season computed from the linear regression equations of temperature on year, day length at average latitude of sowing observations and occurrence of events: sowing (SO), emergence (EM), heading (HE), yellow ripeness (YR) and harvest (HA) in 1959 and 2009 (bottom).

Conclusion and outlook

- Distinct spatio-temporal patterns of oat phenology in Germany could largely be explained by relationships with temperature and day length.
- Good agreement of the thermal and photo-thermal requirements of oat computed in this study with relationships known from field experiments supports the use of the temperature sum concept for large scale application to simulate crop phenology in response to temperature and day length.
- We believe that this applies also to other crops and regions but it needs further testing.

Read more in: Siebert & Ewert, 2012. Agricultural and Forest Meteorology, 152, 44-57.

References

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McMaster, G.S., White, J.W., Hunt, L.A., Jamieson, P.D., Dhillon, S.S., Ortiz-Monasterio, J.I., 2008. Simulating the influence of vernalization, photoperiod and optimum temperature on wheat developmental rates. Annals of Botany 102: 561-569.

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