The biosphere plays a large role in the global carbon cycle and as such in the climate system. The other way around, climatologies constrain vegetation growth. This feedback mechanism expresses itself in the phenology of the land surface (LSP) and is a crucial but uncertain component in Earth system models. An important deficiency is the decomposition of the natural and the anthropogenic signals in this land-atmosphere carbon cycle 1.

We studied the changes in yearly vegetation activity and LSP metrics, and linked these to changes in potential climatological growth constraints (temperature, precipitation, radiation), both at global scale and in more detail for Switzerland. With this, we aim at improved attribution of detected biophysical changes to underlying drivers, both climatological and from other origin.

## Methods

### Data

- CRU TS 3.03
- MODIS/LC (16 km)
- Meteotiss climate grids

### Preprocessing

Climate data has been used from the respective data sources without further corrections. Negative outliers in the GIMMS data (e.g., due to persistent snow) have been filtered using harmonic analyses 3. For the MODIS data, observations flagged as clouds have been removed and the resulting gaps were filled using a structural model in combination with a Kalman filter.

### Trend analysis

Changes in both vegetation activity and climatologies were quantified using a seasonal trend model of the form:

\[ y(t) = \alpha + \beta(t) + \epsilon(t) \]

The slope of the linear term represents the magnitude of change 4.

### Relationships with climatologies

Statistical relationships with potential drivers were established using multiple regression. The trend analysis (climate association) was modeled using a regression approach and the other structural effects using a Gaussian random field. Backfitting assumed an optimal model $\beta(t)$.

\[ \beta(t) = \beta(t) + \sum_{i=1}^{n} \gamma_i \Delta t_i + \epsilon_i \]

### Land-surface phenology

Vegetation index data were preprocessed as described and LSP metrics were subsequently extracted using the endpoint method (figure below). Changes were quantified over the entire period including the mid-late part of the century, while the reliability of the LSP metrics was estimated based on these flags and on the coefficient of variation. Locations with low reliability were neglected.

## Trends in Switzerland since 2000

The Swiss Earth Observation Network (SEON) quantifies functioning of ecosystems and studies links between Earth spheres using field and airborne experiments. Trends in vegetation activity allow attribution of change effects in specific eco-regions, which can be used for down- or upscaling applications.

### Jura and Midlands

Mild regions showed a slight decrease in vegetation activity with various ‘browning hotspots’. Around 40% of the spatial variance in these trends can be statistically attributed to climatologies but these relationships are not straightforward and do not explain most of the hotspots.

### Subequatorial Africa

Large regions show decreases in vegetation activity, unrelated to climatologies. Human activities seem to have enforced the degradation of vegetation systems.

### Eastern Europe

Not all greening can be associated to climate. Land conversions, abandonment of agricultural areas, have likely boosted vegetation activity.

### Boreal divergence

In the North-American (sub)arctic, climate-related greening is conspicuous in tundra regions. Boreal forests do not follow the anticipated greening pattern, which is in dendroecology known as the ‘boreal divergence’ issue. Forest fires may play a role, as well as hydrological feedbacks.

### Trends in climatologies

The last decade shows a slight cooling and drying trend, which may partly explain the reduction in vegetation activity. However, this relationship should be interpreted with care: changes over a 14-year period may not represent actual climate change but may be influenced by anomalous years.

## References