Sensitivity of phenology models to the selection of driving meteorological datasets

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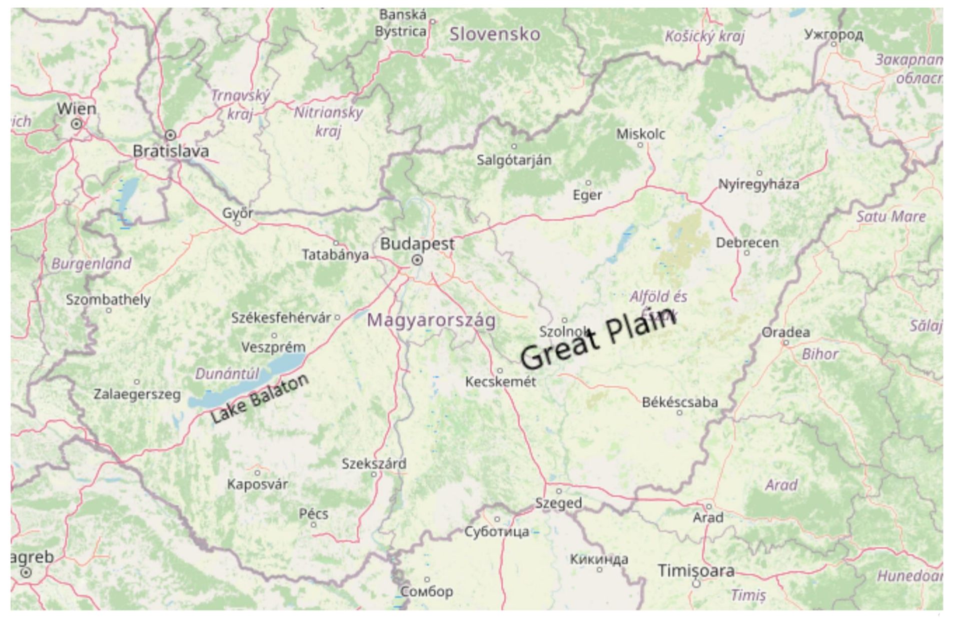
Introduction

Plant phenology focuses on the annual repetitive development phases of the terrestrial vegetation. Observations indicate changes in the phenological cycle of the vegetation worldwide that are clear indicators of climate change. For this reason it is necessary to construct and continuously improve phenology models. The aim of the present study is to use multiple phenology models and driving meteorological datasets together with observation-based start of season (abbreviated as SOS) estimates. We seek to provide information about the consequences of the choice of phenology model structure and driving meteorological dataset.

Meteorological and remote sensing datasets

	ERA5	CarpatClim	FORESEE	NDVI3g	this study
period	1979-near real time	1961-2010	1951-2100	1982-2013	1982-2010
resolution	0.25°×0.25°	0.1°×0.1°	1/6°×1/6°	1/12° × 1/12°	0.1°×0.1°
citation	Copernicus Climate Change Service, 2017	Szalai et al., 2013	Dobor et al., 2015	Kern et al., 2016	



The study area is **Hungary**. The pixels of Lake Balaton and Budapest were excluded due to fact that satellite dataset provided unrealistic values over lakes and urban areas.

Phenology models:

It is a major challenge to scale up the species-specific or individual based phenology models to regional, continental or global scale (White et al., 1997; Chuine et al., 2000; Richardson et al., 2013). This study seeks solutions that can be used to simulate climate-driven changes in the timing of the climatological onset of leaf growth.

(1) Warming Model (WM):
SOS is regulated by heatsum. WM is used in IBIS (Integrated BIosphere Simulator) and CLM-DGVM (Community Land Modell–Dynamic Global Vegetation Model; Jeong et al., 2012).

(2) Chilling-Warming Model (CWM):
SOS is affected by heatsum and chilling requirement. CWM is used in ORCHIDEE (ORganizing Carbon and Hydrology in Dynamic EcosystEms) and the SEIB-DGVM (Spatially Explicit Individual Based-Dynamic Global Vegetation Model; Jeong et al. 2012).

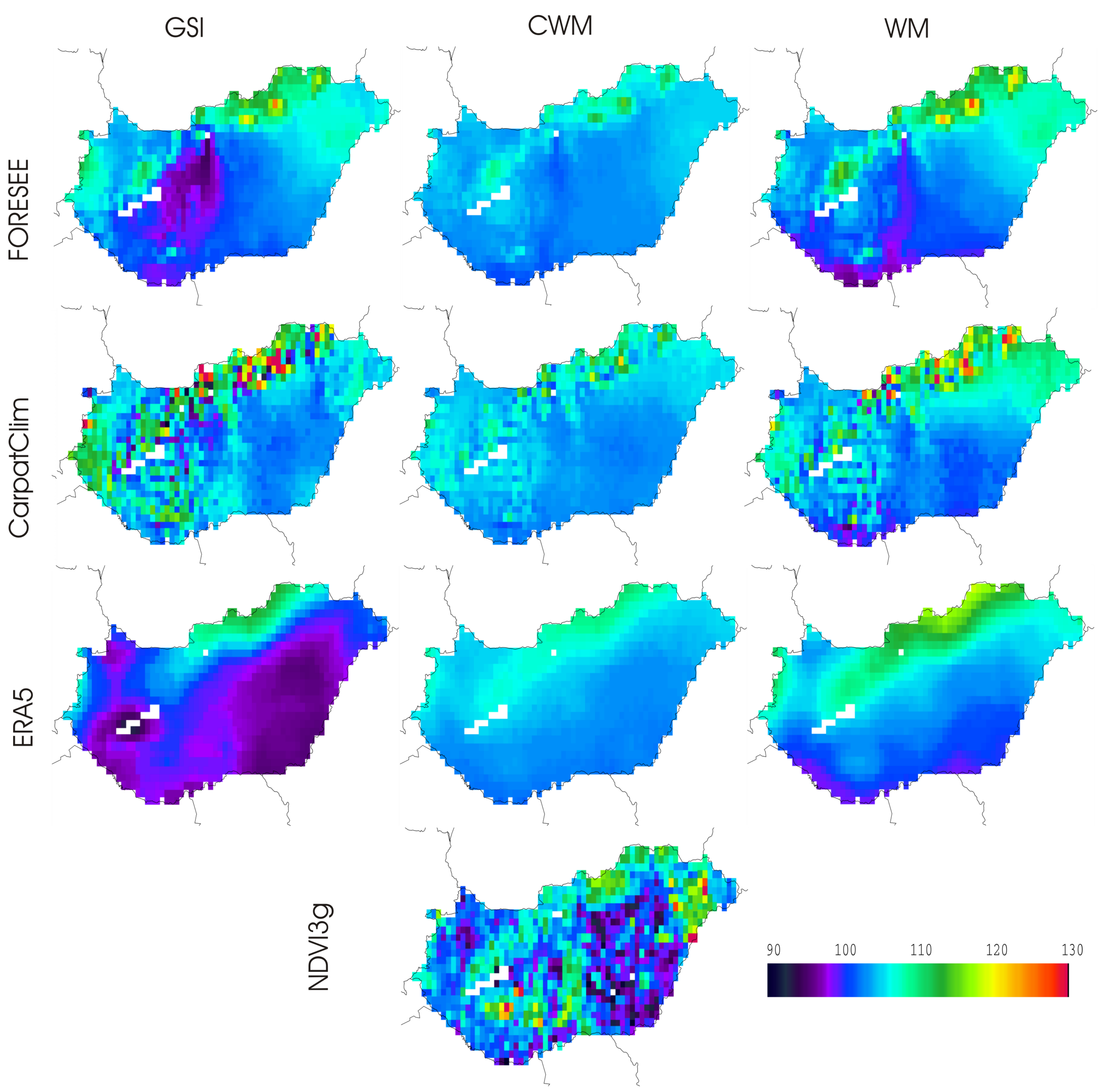
(3) Growing Season Index (GSI):
SOS is affected by minimum temperature, the vapor pressure deficit (VPD) and the photoperiod (Jolly et al., 2005).

	CWM	WM	GSI	CWM	WM	GSI	CWM	WM	GSI	NDVI3g
driving meteorology	CarpatClim			FORESEE			ERA5			
median	104	106	103	104	105	102	104	105	98	104.4
standard deviation	2.4	4.3	6.1	1.9	3.5	4	2	3.6	4	6
5th percentile	102	101	98	102	100	97	102	100	94	95.5
95th percentile	109	114	114	107	111	109	108	113	108	115.6

The table shows the spatial statistics of the SOS climatologies for 1982-2010 period.

- The observation based median SOS date is DOY 104 (14 April in regular years). Model-database combinations typically reproduce the observed mean given the optimization of the models.
- Standard deviation (i.e. spatial variability) is underestimated by the model-database combinations.
- According to the observed data the earliest SOS is DOY 95 (5 April), while the latest is DOY 116 (26 April).
- For the 5th percentile the GSI model provides better estimates, while for the 95th percentiles the WM model provides somewhat better predictions.

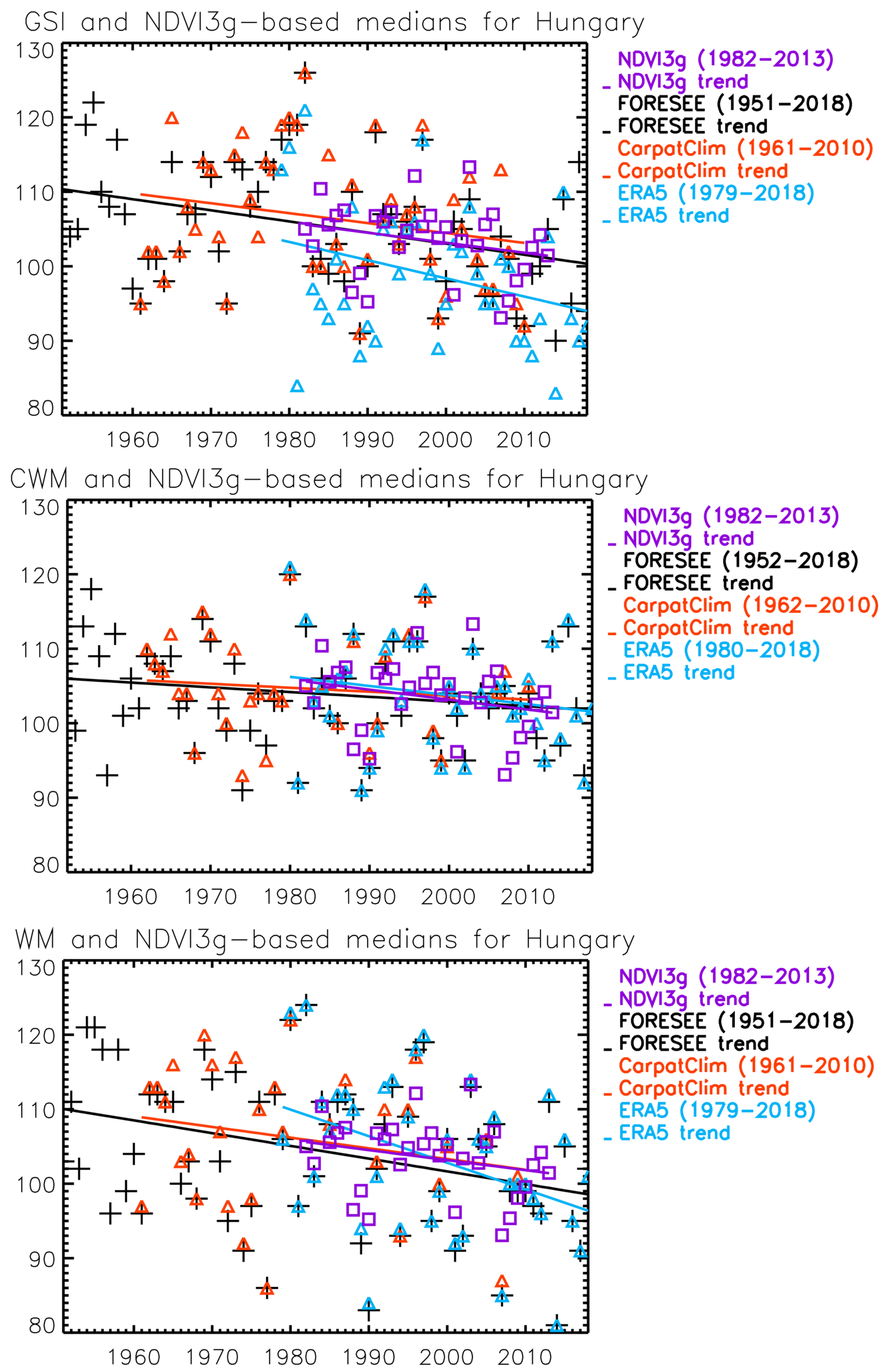
Results and discussion



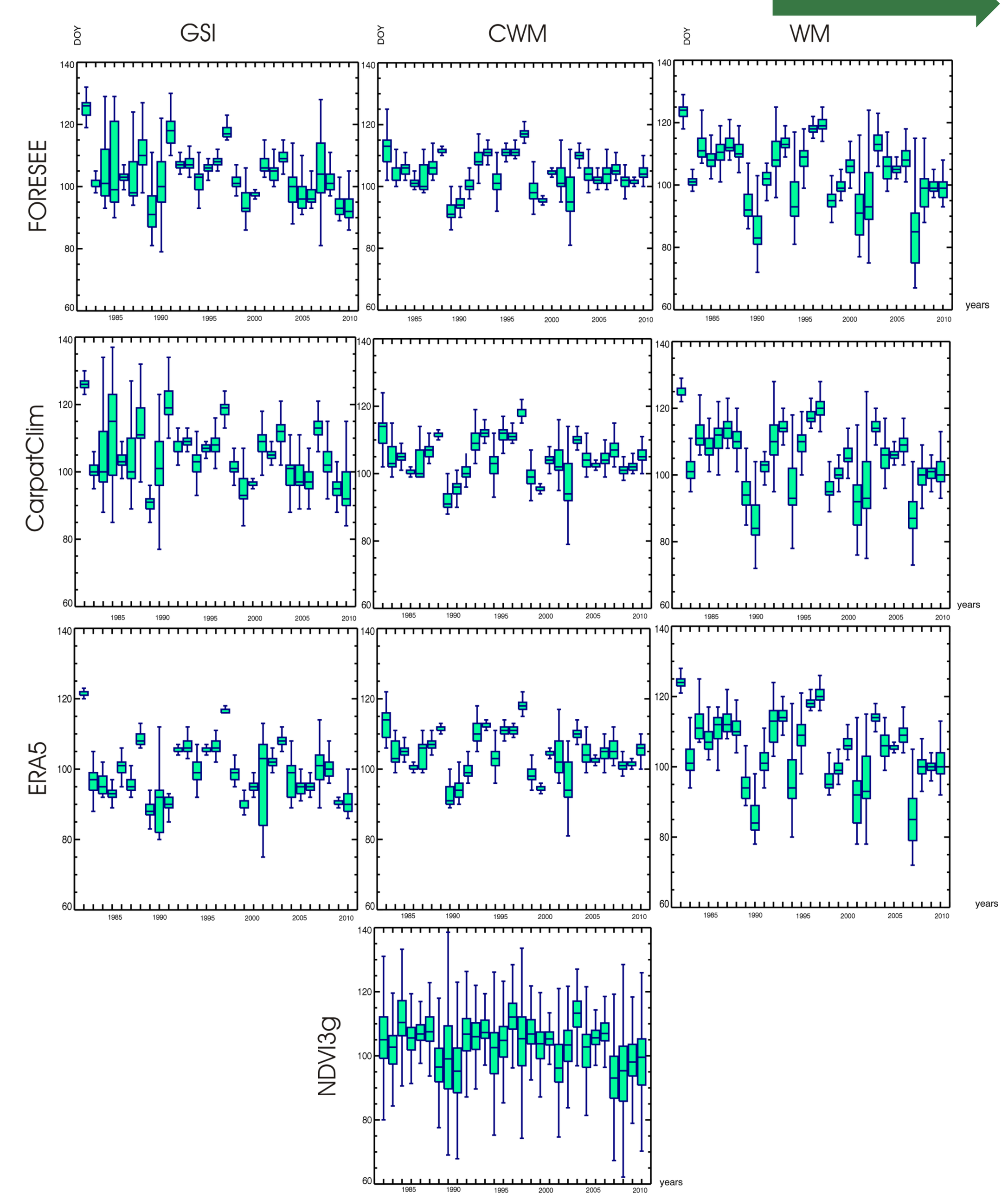
SOS climatology maps calculated from the 3 SOS models, using 3 different meteorological datasets for the 198-2010 time period (defined by the start date of the NDVI3g dataset and the limited temporal availability of the CarpatClim dataset). Bottom map shows the MODIS adjusted NDVI3g-based SOS estimates.

- Observation based SOS → earliest on the eastern part of the Great Plain.
- Model results disagree about the location of the early SOS regions. → GSI driven by FORESEE & ERA5 and WM driven by FORESEE → early dates for west-southwest.
- Spatial features: CarpatClim provides the highest details, ERA5 is quite smooth.
- Visually, the NDVI3g based SOS climatology is best represented by the CarpatClim based GSI.

The medians and the trends of the observations and the 3 models driven by 3 datasets.



- All the models driven by any dataset and the observation shows advanced SOS.
- The trends of CarpatClim and FORESEE are quite similar
- CWM has the most similar results according to the driving meteorology.



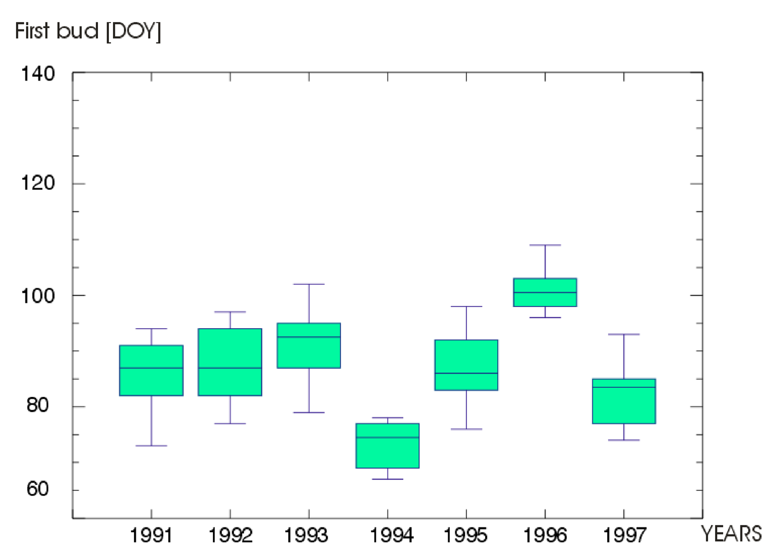
Statistics about the interannual variability (IAV) of the modelled and observed SOS for the whole country in the form of box-whisker plots for the 1982–2010 time period

- There is relatively high spatial variability within the specific years for the GSI and the WM, where ERA5 driven GSI is exception.
- CWM provides estimate that is closest to the NDVI3g-based IAV.
- WM provides the highest IAV that reaches 10.2 when the model was forced with ERA5 and FORESEE.

Future plans

We are planning to widen the research and examine specific vegetation (or plant functional) types. For this purpose we need field observations (Menzel et al., 2006).

Courtesy to the botanical garden of the Eötvös Loránd University we have access to a dataset, containing data on the developmental stages for more than 100 species, which has not been analyzed before. We plan to use this dataset with PEP725 data (PEP725 is not available for Hungary) to investigate the phenological cycle of vegetation in Central Europe.



Box-whisker plots for 10 species of Tulips from the dataset of the Botanical Garden, which is located in Budapest, for 1991-1997.

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