Plant phenology evaluation of CRESCENDO Land Surface Models

Deborah Hemming, Daniele Peano, Stefano Materia, Taejin Park, David Wårlind, Yuanchao Fan, Hanna Lee, Andy Wiltshire, and Chris D. Jones

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Introduction

A new generation of land surface models (LSMs) have been developed in the framework of the EU- funded CRESCENDO project aiming to improve understanding of the Earth system as part of the community CMIP6 effort.

These new LSMs explicitly represent key processes in the carbon and nitrogen cycles, enabling more realistic vegetation-climate interactions to be simulated. For instance, vegetation phenology, the seasonality of vegetation, is explicitly represented in all these new LSMs. Intra- and inter- annual variations in vegetation phenology can substantially influence land-atmosphere exchanges of energy, moisture and carbon. Changes in phenological events also provide clear indicators of climate impacts on ecosystems.

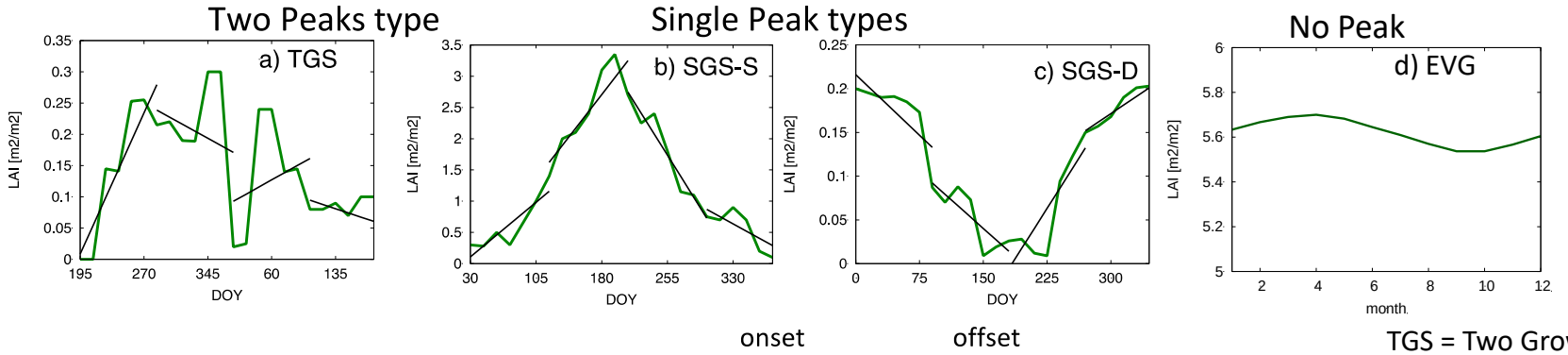
We evaluate the global scale timing of growing season (Leaf Area Index, LAI) onset, offset, peak and trough from these LSMs, relative to the MODISc6 satellite-derived LAI product.

Models

1. CLM 4.5;
2. CLM 5.0;
3. JULES-ES;
4. JSBACH;
5. LPJ-GUESS;
6. ORCHIDEE-CN;
7. SURFEX.

Methodology using LAI

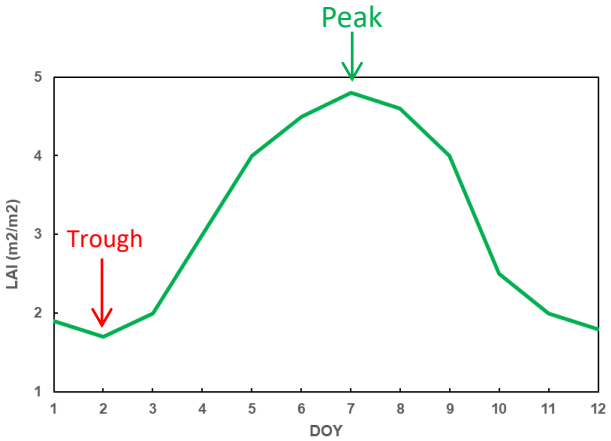
Onset and offset timings



TGS = Two Growing Season;
SGS = Single Growing Season;
SGS-S = Summer peaking;
SGS-D = summer Dormancy;
EVG = evergreen.

The Four Growing Season Type (4GST) methodology[1] is applied in identifying onset and offset timings starting from LAI annual shape.

Peak and trough timings



Peak timing is the month (from Jan-Dec) with the highest monthly mean LAI.

Trough timing is the month with the lowest monthly mean LAI.

10-year climatology of LAI 2000-2009 used.

[1]Peano et al. (2019), Global Variability of Simulated and Observed Vegetation Growing Season, *JGR:Biogeosciences*

Results – Growing Season Onset

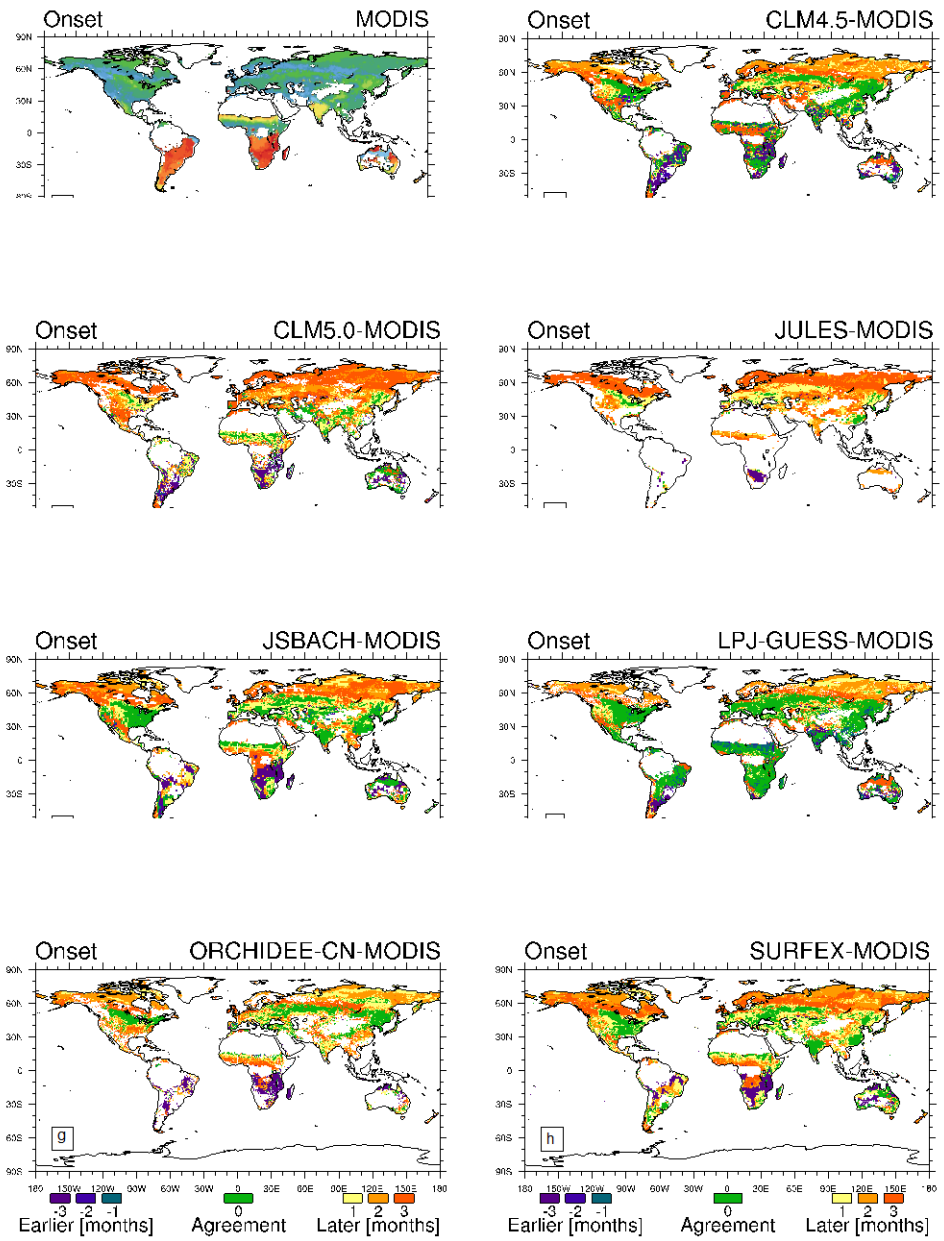


Figure: Global climatological (averaged over 2000-2011) growing season onset for (a) MODIS. Differences in onset timings between MODIS and (b) CLM 4.5; (c) CLM 5.0; (d) JULES; (e) JSBACH; (f) LPJ-GUESS; (g) ORCHIDEE-CN; (h) SURFEX.

Table: Fraction of land grid-cell in agreement with MODIS for each land surface model in Onset timings. Green shaded areas in Figure.

LSM	Agreement
CLM 4.5	17.0
CLM 5.0	8.5
JULES	4.8
JSBACH	18.9
LPJ-GUESS	20.9
ORCHIDEE-CN	16.3
SURFEX	17.0

- Larger agreement with observation is obtained in the North Hemisphere (NH) compared to South Hemisphere (SH);
- High agreement is attained by LPJ-GUESS;
- Low agreement is obtained by JULES;
- High agreement in NH is reached by LPJ-GUESS;
- High agreement in SH is achieved by LPJ-GUESS and JSBACH.

Results – Growing Season Offset

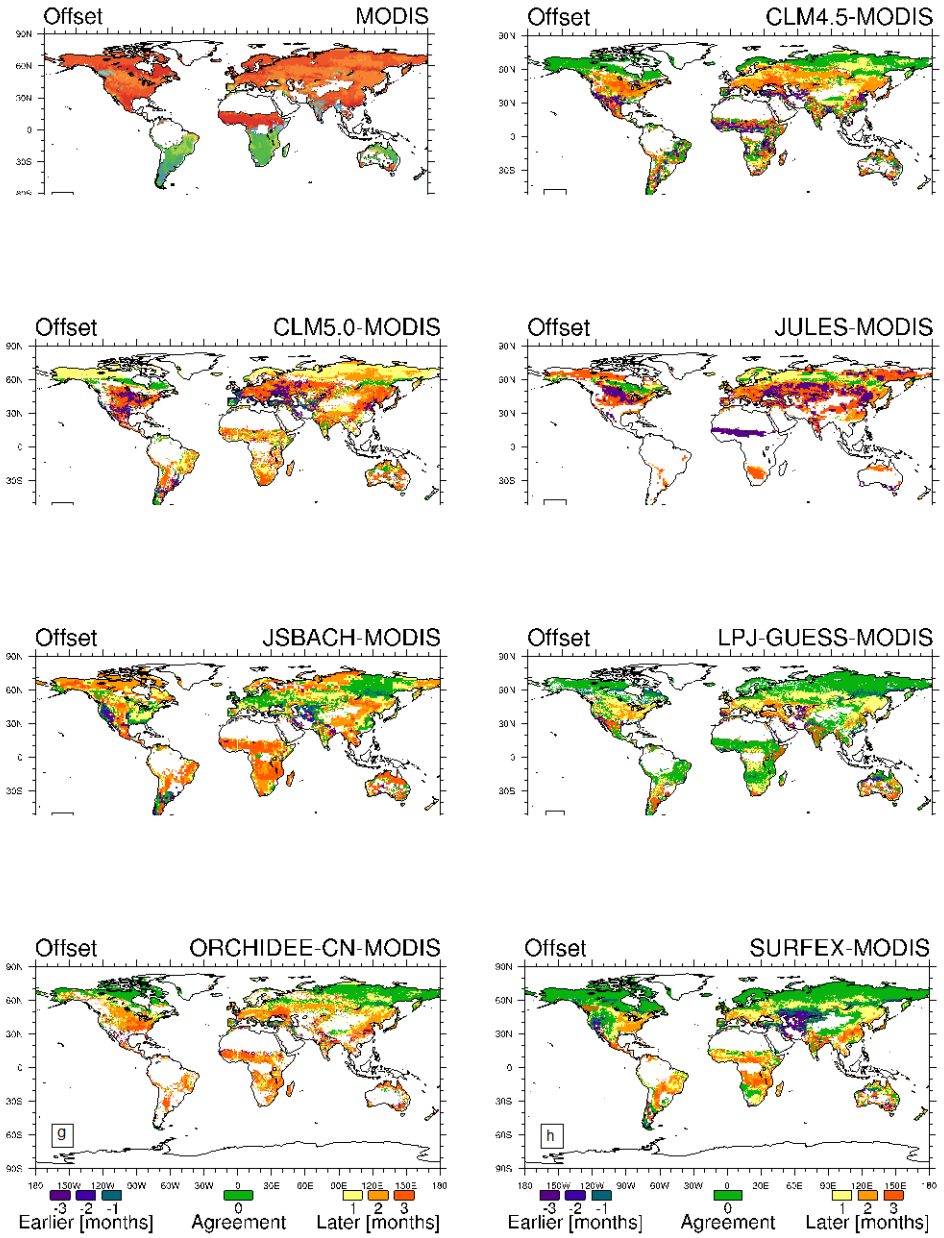


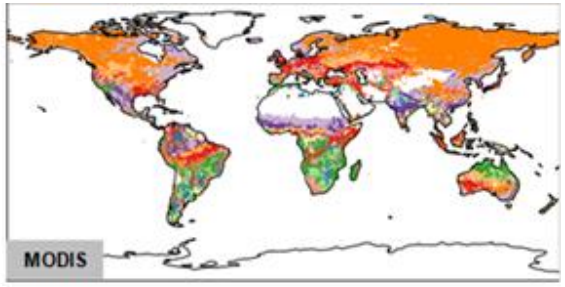
Figure: Global climatological (averaged over 2000-2011) growing season offset for (a) MODIS. Differences in offset timings between MODIS and (b) CLM 4.5; (c) CLM 5.0; (d) JULES; (e) JSBACH; (f) LPJ-GUESS; (g) ORCHIDEE-CN; (h) SURFEX.

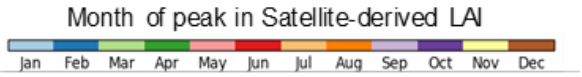
Table: Fraction of land grid-cell in agreement with MODIS for each land surface model in Offset timings. Green shaded areas in Figure.

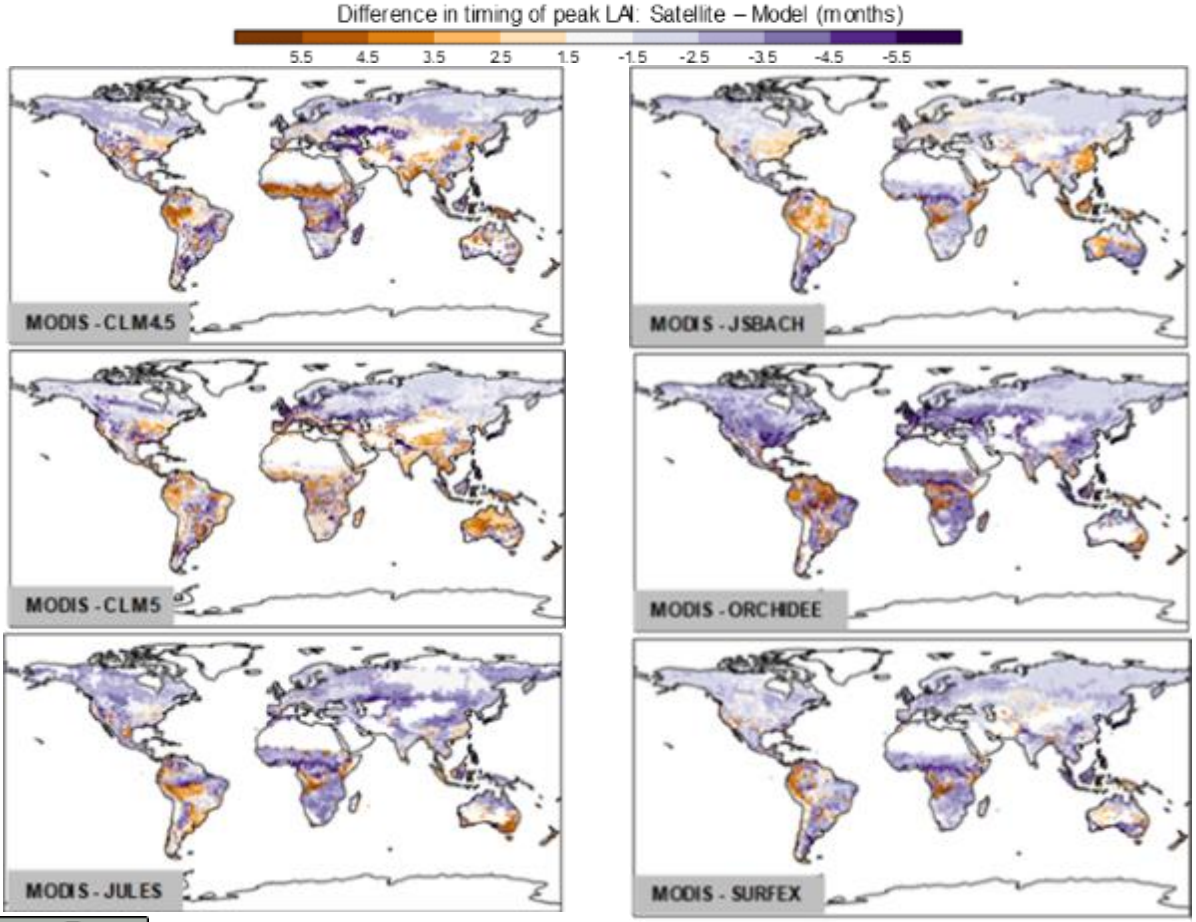
LSM	Agreement
CLM 4.5	27.4
CLM 5.0	8.6
JULES	8.6
JSBACH	14.4
LPJ-GUESS	24.9
ORCHIDEE-CN	25.3
SURFEX	21.1

- Larger agreement with observation is obtained in the NH compared to SH;
- High agreement is attained by CLM 4.5;
- Low agreement is obtained by JULES and CLM 5.0;
- High agreement in NH is reached by LPJ-GUESS;
- High agreement in SH is achieved by LPJ-GUESS.

Results – Peak and Trough of Season







- All models show widespread delay in peak of season;
- Boreal and temperate NH are 1.5-3.5 months delayed in models;
- Other regions show variable peak timings between models;
- All models show similar month of lowest LAI (trough) to MODIS (maps not shown).

Hemming et al. (in prep.), Plant phenology evaluation of CRESCENDO land surface models. Part II: peak and trough.

Conclusions

- LSMs exhibit the largest agreement with the MODIS onset and offset timings in the NH mid- and high-latitude regions and show low skill in the SH. The SH features large phenology variability and the majority of LSMs calibration areas are located in the NH, which can explain better results in NH.
- Most LSMs show a slightly higher skill in the offset than in the onset timing.
- LPJ-GUESS, CLM4.5, JSBACH and SURFEX exhibit good agreement with observations for the SH.
- Good results in the NH are obtained by ORCHIDEE-CN, LPJ-GUESS and CLM4.5.
- All LSMs show widespread delay in peak of season.
- Boreal and temperate NH zones show consistent delays in peak of season by 1.5 to 3.5 months for all models.
- Timing of monthly minimum LAI (trough) is modelled well by all LSMs.