Global variability of simulated and observed vegetation growing season

Daniele Peano, D. Hemming, S. Materia, C. Delire, Y. Fan, E. Joetzjer, H. Lee, J. E.M.S. Nabel, T. Park, P. Peylin, D. Wårlind, A. Wiltshire, and S. Zaehle

16 Sep 2020, 106 Congresso SIF

Introduction

Società Italiana di Fisica

Plant phenology studies the periodic plant life cycle.

It is influenced by environmental conditions:

- Light availability
- Soil moisture
- Temperature
- Precipitation

CRESCENDO

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Changes in spring and autumn phenology are reported in recent decades under global warming.

Green leaves are at the interface between land and atmosphere for:

- Exchange of energy
- Exchange of CO_2
- Exchange of momentum

CRESCENDO

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Land Surface Models include a more detailed description of land processes such as:

* Carbon cycle * Nitrogen cycle * Plant phenology * water cycle

Evaluations of these models show:

1. bias of ≅ 2 weeks in LSMs representation of the beginning and end of the growing season, and low skill in simulating the observed inter-annual phenology variability leading to biases in the gross ecosystem photosynthesis;

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2. Low skill in capturing a widespread lagged plant productivity responses across northern ecosystems associated with warmer and earlier springs;
3. The length of the active vegetative season is overestimated in the northern hemisphere.

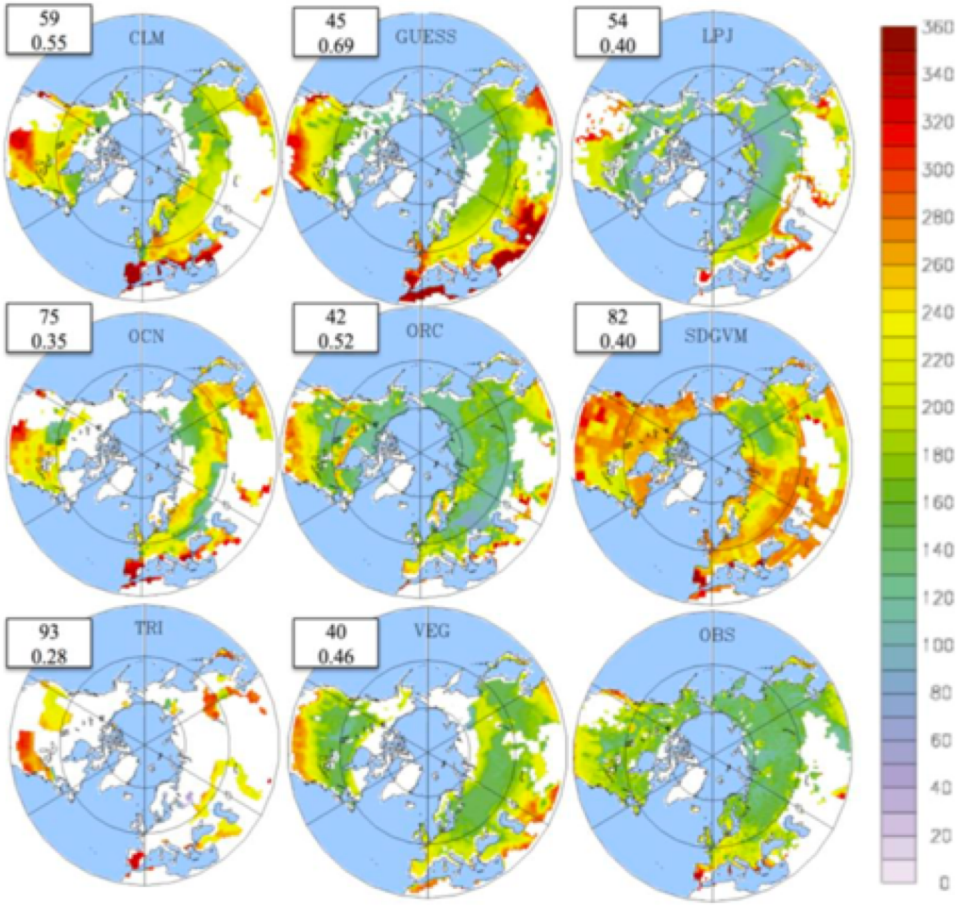

Figure: Growing season length as evaluated in [3]

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Methodology

Previous phenology analysis focused on specific biomes or regions, such as NH mid- and high-latitude regions (above 30° N).

Here, the plant phenology is evaluated at **global scale** by means of the "4 growing season type" (4GST) methodology[1].

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4GST uses the vegetation metrics Leaf Area Index (LAI) as proxy for the phenology .

LAI is also the key variable by which LSMs scale-up leaf-level processes to canopy and ecosystem scale exchanges of carbon, energy, and water.

4GST identify four common types of phenology:

1. evergreen;
2. Single growing season peaking in summer;
3. Single growing season with summer dormancy;
4. Two growing seasons.

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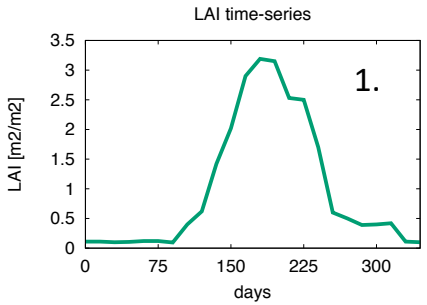
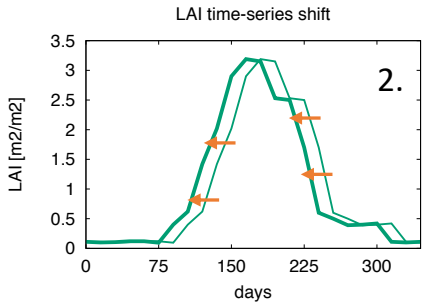
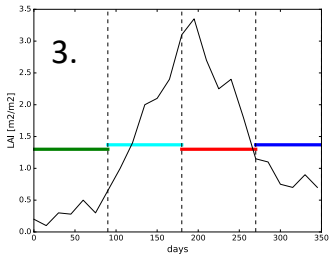
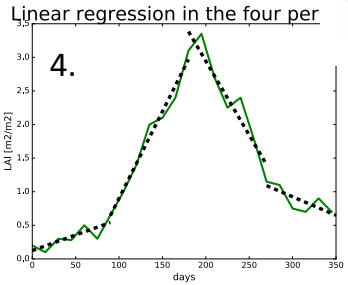
Methodology – 4GST









1. Extract LAI time series in each land grid cell

2. Shift LAI time series to center LAI maximum

3. Divide LAI time series in four periods

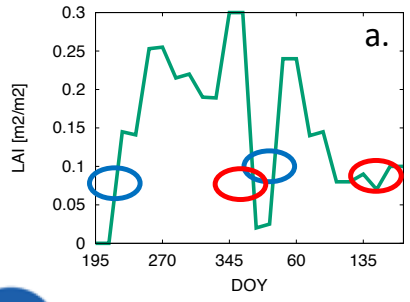
4. Linear regression in the 4 periods to identify phenology types

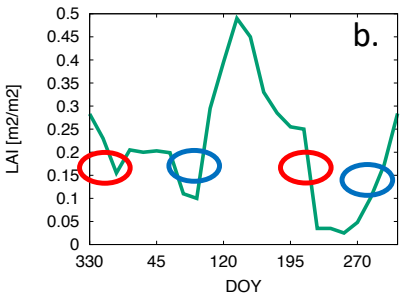
growing season start
growing season end

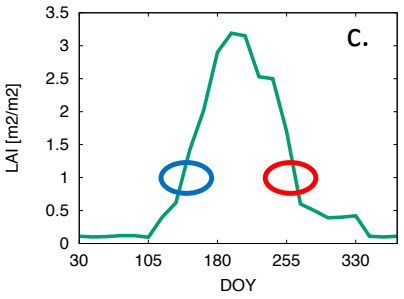
Two Peaks types

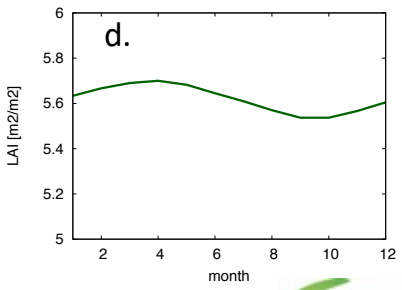
Single Peak

No Peak









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Methodology

The European CRESCENDO project fostered the development of a new generation of LSMs to be used as the land component of the CMIP6 Earth System Models:

1. Community Land Model version 4.5 (CLM4.5);
2. Community Land Model version 5.0 (CLM5.0);
3. JULES-ES;
4. JSBACH;
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- Land only simulations;
- Period 2000-2011;
- CRUNCEPv7 as atmosphere forcing
- LUH2 as land use forcing;
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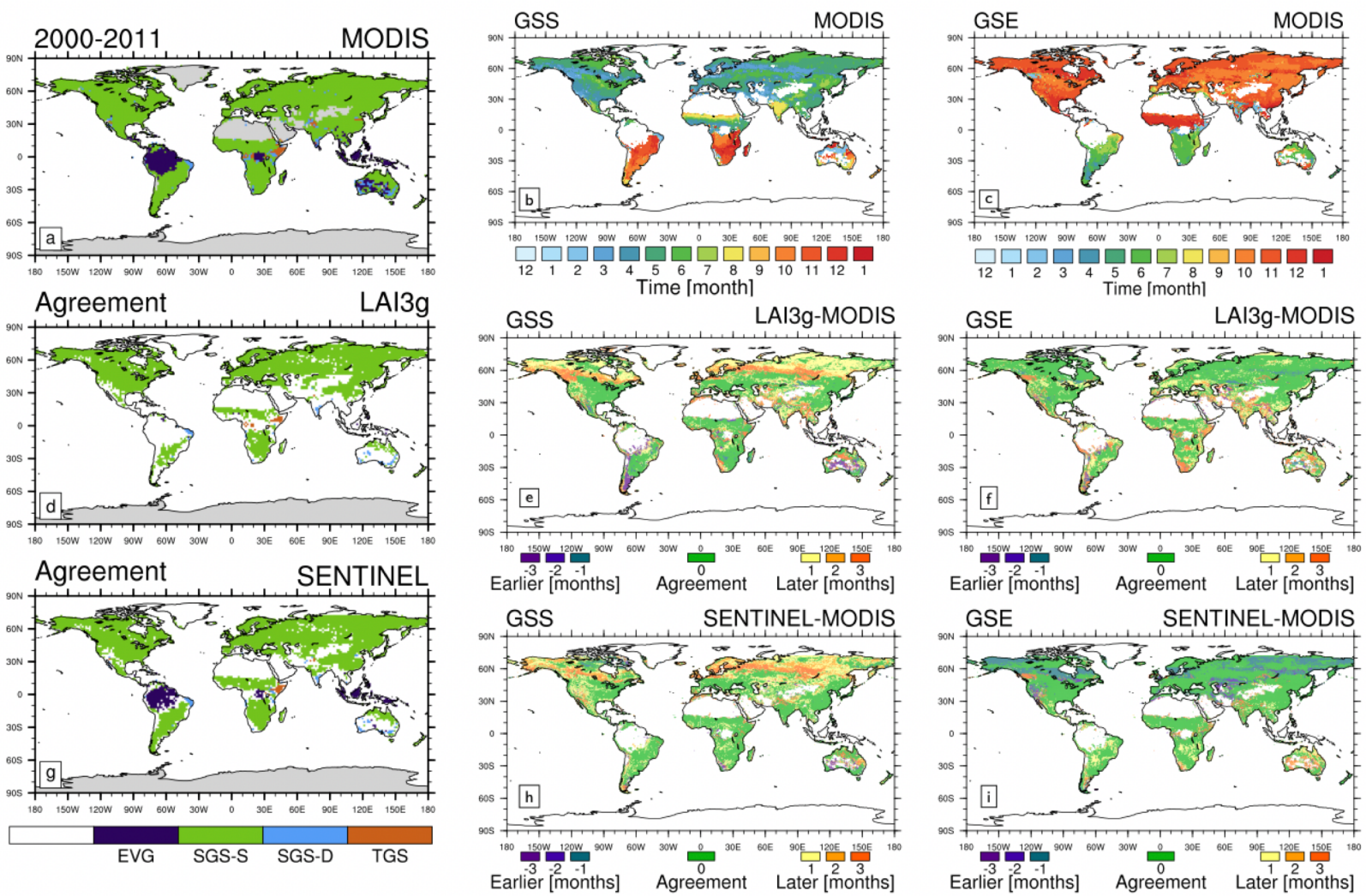
Global validation is performed by means of satellite products:

1. LAI3g;
2. SENTINEL;
3. MODISv6.

Results - Satellite

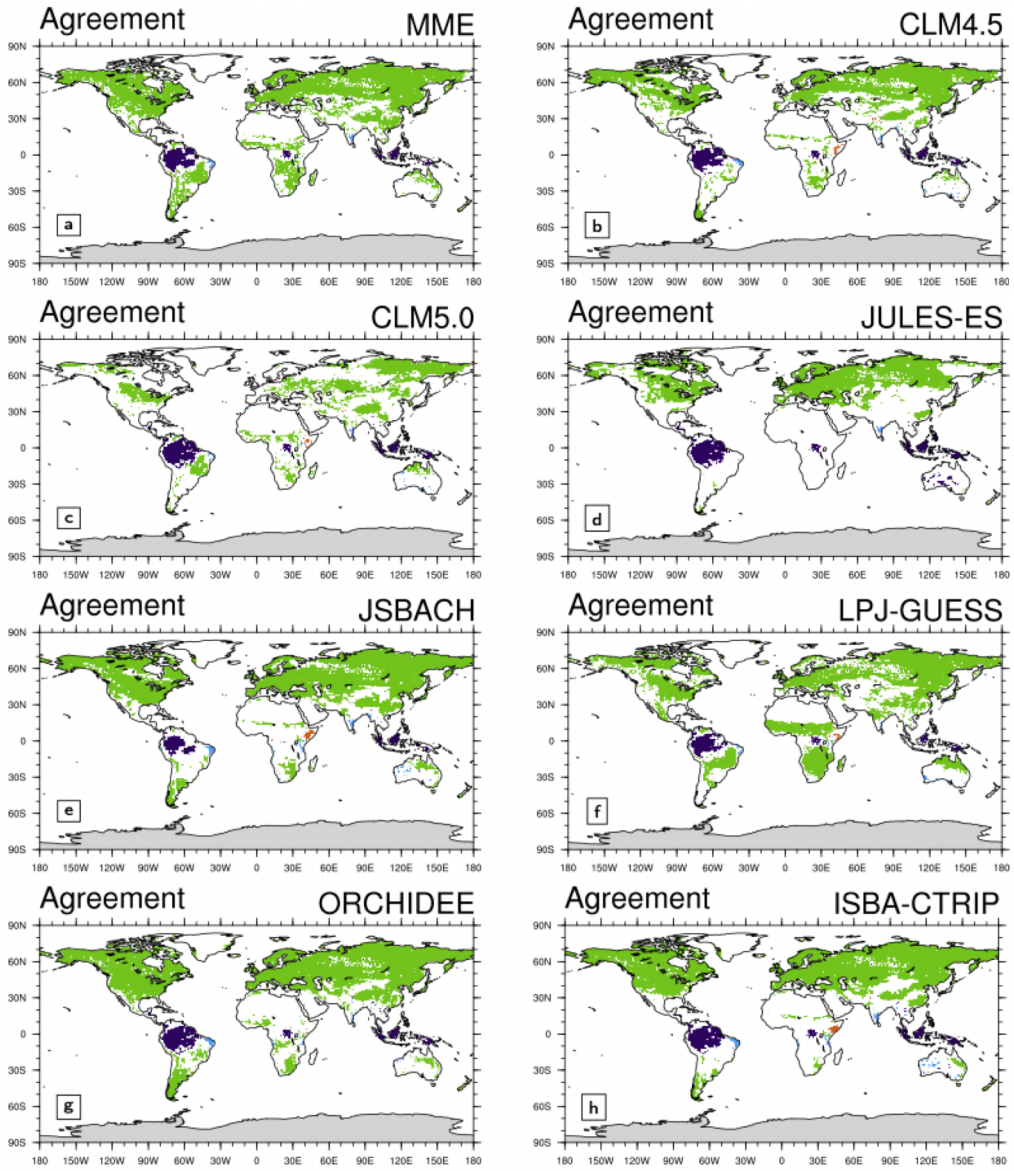


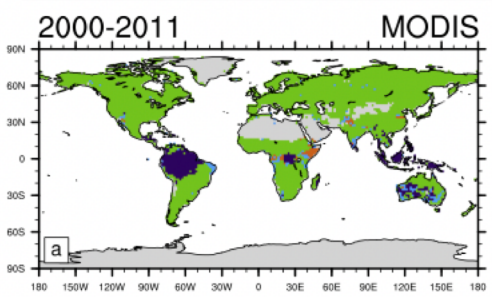
Growing season type agree on 80% of land.
Low agreement in TGS.

Growing season start and end (GSS and GSE) agree on 75% of land with one month tolerance.
LAI3g and SENTINEL anticipate GSS compared to MODIS in North Hemisphere

*Peano, D., et al..: Plant phenology evaluation of CRESCENDO land surface models – Part I: start and end of growing season, Biogeosciences Discuss.,2020

Results – Growing season type





Comparison with **MODIS** distribution

- SGS-S captured in the NH;
- Difficulties in capturing TGS;
- The SH shows reduced agreement.

Model	EVG	SGS-S	SGS-D	TGS	Total
MME	**51**	**77**	**24**	**1**	**70**
CLM4.5	58	64	48	19	61
CLM5.0	73	44	36	17	45
JULES-ES	95	48	7	1	48
JSBACH	36	72	51	14	65
LPJ-GUESS	55	74	33	15	68
ORCHIDEE	72	80	33	8	74
ISBA-CTRIP	75	74	59	13	71

Percentage of agreement

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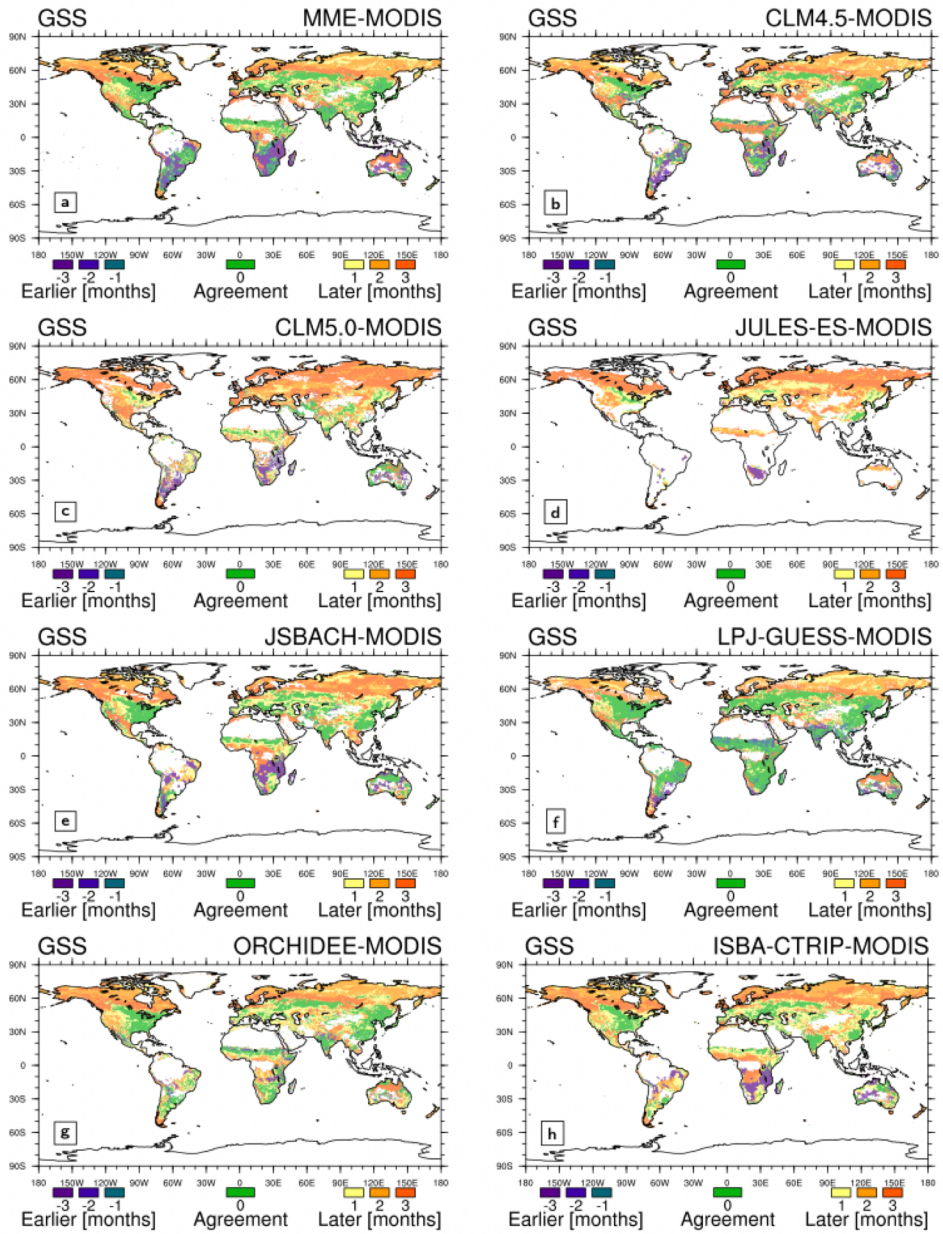
Results – Growing season start



Model	Agreement	Difference*
MME	**15.8**	**0.56**
CLM4.5	14.6	0.54
CLM5.0	6.5	0.81
JULES-ES	2.7	1.23
JSBACH	16.7	0.35
LPJ-GUESS	17.3	0.37
ORCHIDEE	19.1	0.64
ISBA-CTRIP	16.0	0.44

*Positive later, negative earlier

- LSMs simulate a **later** start of growing season;
- NH higher agreement than SH;
- Good skill by LPJ-GUESS, JSBACH, ORCHIDEE;
- Low skill by JULES-ES, CLM 5.0.

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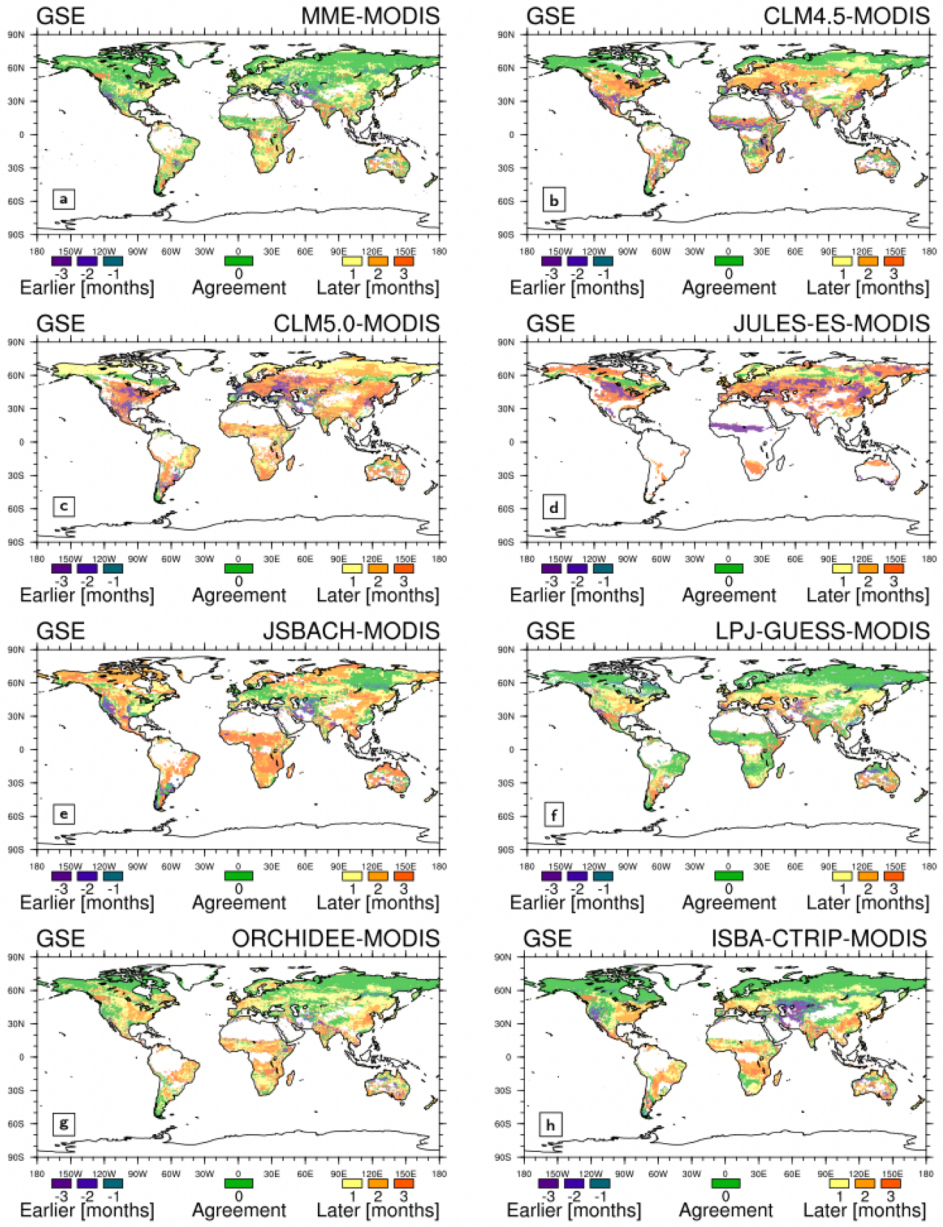
Results – Growing season end

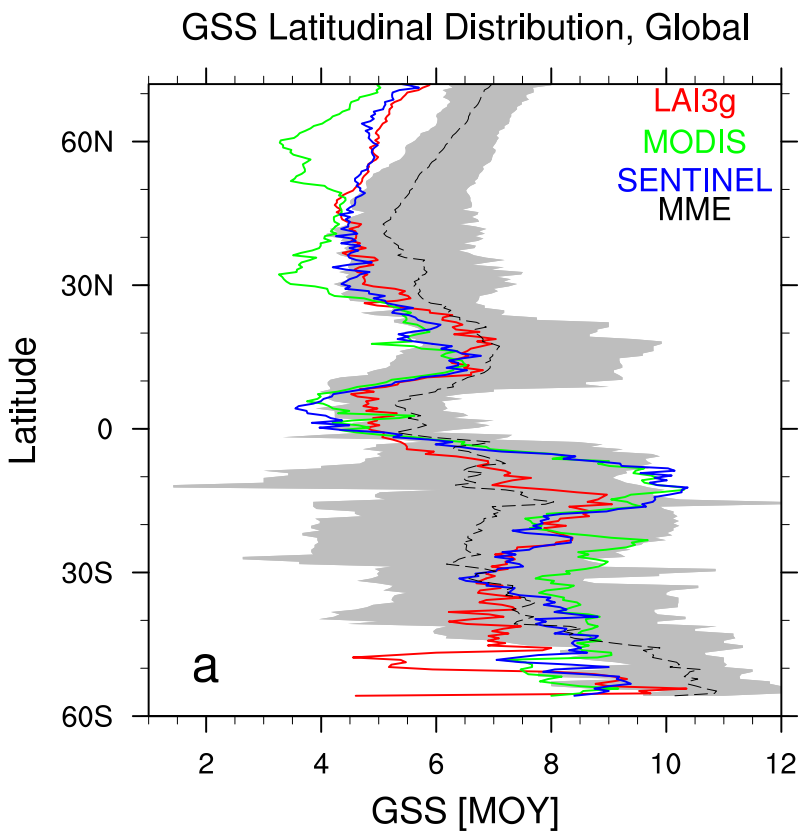


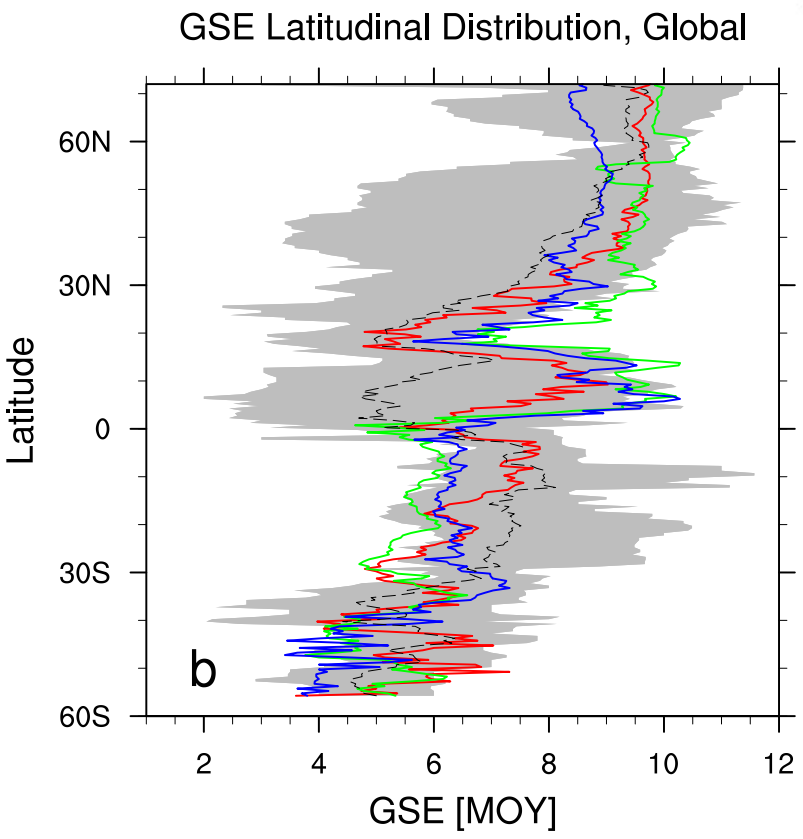
Model	Agreement	Difference*
MME	25.1	-0.49
CLM4.5	23.5	-0.30
CLM5.0	6.5	-1.15
JULES-ES	4.9	-2.26
JSBACH	12.6	-0.28
LPJ-GUESS	20.6	0.14
ORCHIDEE	26.4	-0.10
ISBA-CTRIP	19.9	-0.30

*Positive later, negative earlier

LSMs simulate an **earlier** end of growing season, except LPJ-GUESS;
NH higher agreement than SH;
Good skill by LPJ-GUESS, CLM4.5, ORCHIDEE;
Low skill by JULES-ES, CLM 5.0.

Results





- The GSS bias ranges between -1.8 months and +2.0 months;
- The GSE bias ranges between -3.0 months and +1.3 months;
- The CRESCENDO LSMs correctly simulate the GSE timings north of 60°N;
- Biases are more evident in localized area such as Tropical Africa;
- LSMs overestimate the observed trends in both GSS and GSE timings.

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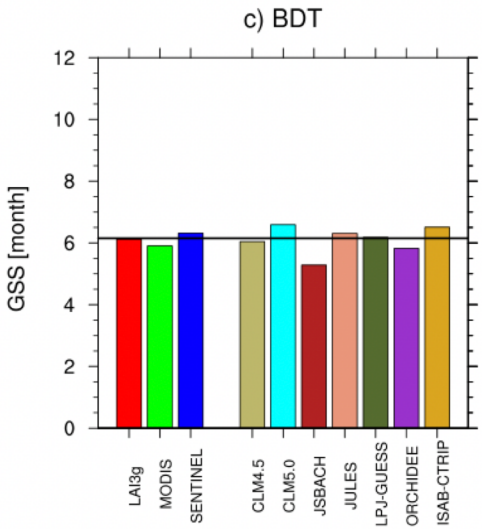
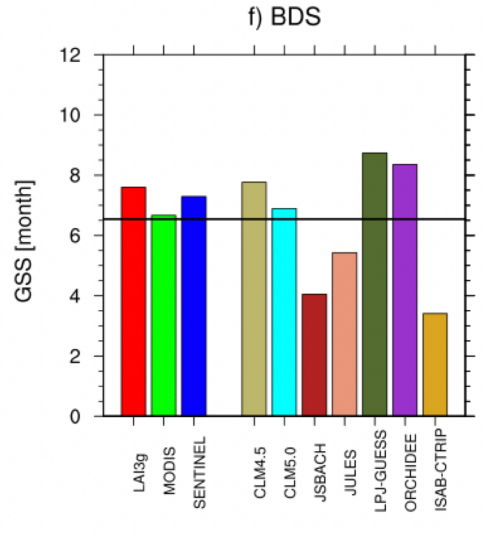
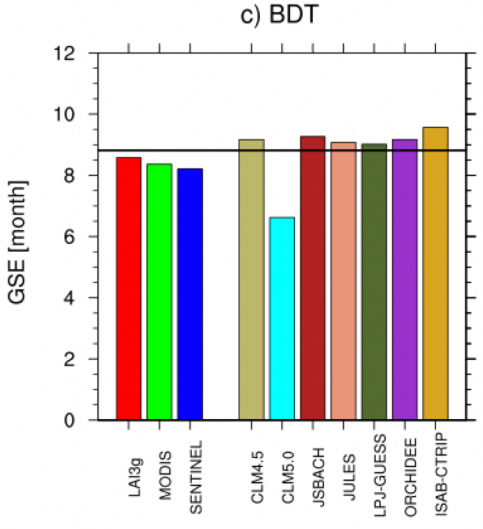
Results

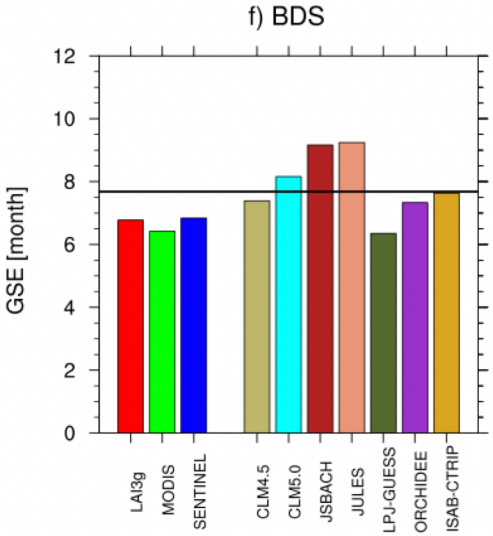
START



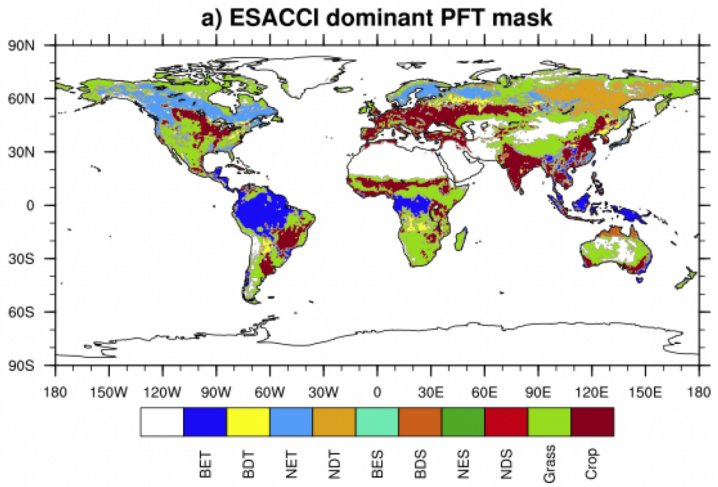


END





- GSS shows smaller variability compared to GSE;
- BDT shows small variability among LSMs;
- BDS shows high variability among models;
- GSS delayed compared to observations;
- GSE shows heterogeneous outcomes.



BDT = Broadleaf Deciduous Trees; BDS = Broadleaf Deciduous Shrubs

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- LSMs exhibit later growing season start and earlier growing season end leading to almost one month shorter growing season;
- The latitudinal distribution of growing season timings highlight biases up to 3 months in LSMs compared to observations;
- At biome level, high variability is simulated in Broadleaf Deciduous Shrubs areas while good agreement is reached in Broadleaf Deciduous Tree regions.

Outlook

- Evaluate phenology in coupled configuration to assess the impact of atmosphere condition on phenology;
- Evaluate inter-annual variability and decadal trends using high frequency data and longer time scale data;
- Assess the impact of land use change, climate, and atmosphere forcing on vegetation and its life cycle.

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THANKS