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Validation of VIIRS Land Surface Phenology Product using Multiple Reference Data

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Abstract- **Land surface phenology (LSP) at 500m pixels is retrieved from the Visible Infrared Imaging Radiometer Suite (VIIRS). The VIIRS LSP product is validated using three different datasets: national phenology networks, a reference generated by fusing harmonized Landsat and Sentienal-2 (HLS) with ground-based PhenoCam time series, and VENuS time series. The results suggests that 500m VIIRS LSP characterizes well spatial and temporal variation in vegetation phenology with a uncertainty generally less than 10 days.**

1. In-situ observations of species-specific plant phenology

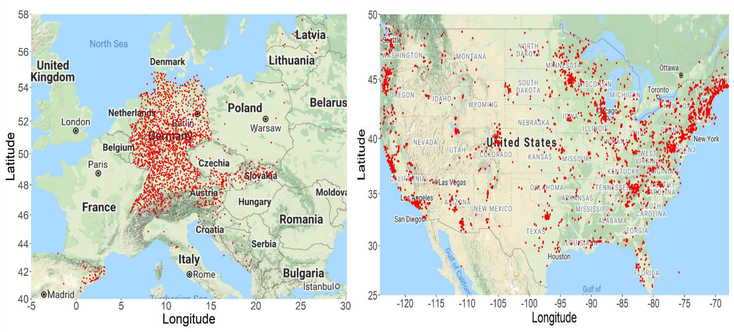


Fig.1. Distribution of in-situ sites in the Pan European Phenology Project (PEP725) Network (N=1899) and the United States of America National Phenology Network (USA-NPN) (N=1477) from 2013–2020

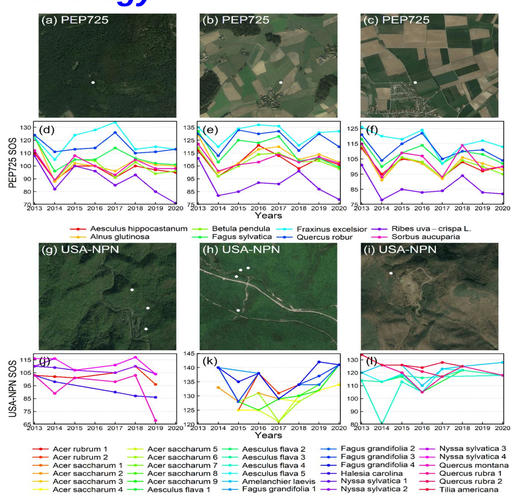


Fig. 2. Variations of In-situ SOS (start of season) for individual plants in field sites (white dots) within a 2.5×1.5 km^2 area of deciduous forest in the PEP725 (a-f) and USA-NPN (g-l).

2. Phenometrics detected from synthetic gap-free EVI2 time series generated by fusing harmonized Landsat and Sentienal-2 (HLS) with ground-based PhenoCam observations

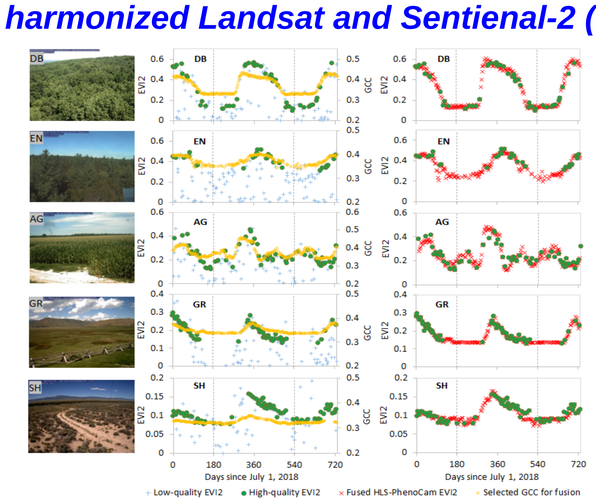


Fig. 3. Fusing HLS EVI2 (two-band enhanced vegetation index) time series with PhenoCam GCC (Green Chromatic Coordinate) observations to generate 30 m synthetic gap-free HLS-PhenoCam time series for deciduous forest (DB), evergreen forest (EN), agriculture (AG), grass (GR), and shrub (SH). The time series are from 1 July 2018 to 30 June 2020.

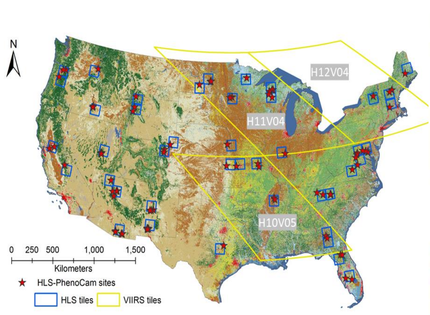


Fig. 4. Geographical distribution of 78 regions included in the HLS-PhenoCam LSP dataset across various ecosystems in the USA. Each region covers 10 × 10 km with at least one PhenoCam site. The background is 30 m land cover types.

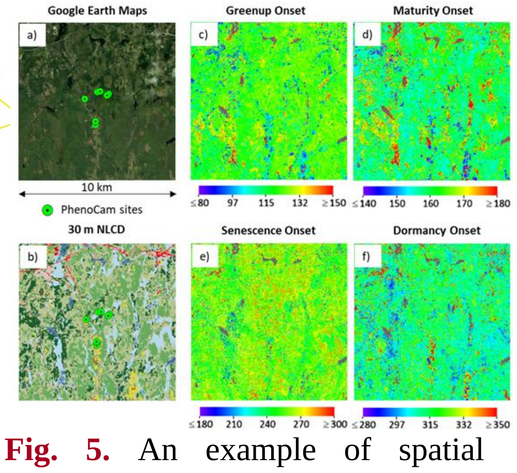


Fig. 5. An example of spatial patterns of HLS-PhenoCam phenometrics (centred location at 42.53°N and 72.18°W). a) is the Google Earth Map, b) is the 30 m land cover types, (c-f) are four key phenometrics (greenup, maturity, senescence, and dormancy onsets) detected from the HLS-PhenoCam EVI2 time series.

3. Phenometrics from VENuS VM1 Time Series

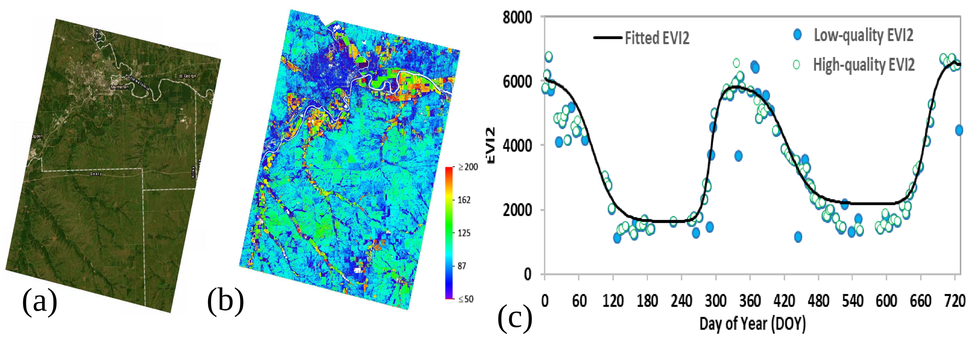


Fig.6. Phenometrics calculated from the VENµS VM1 times series that are at high spatial (5 m) and temporal (~2 days) resolutions in a 28 km swath in the central USA. (a) Google Earth map, (b) greenup onset timing (day), (c) VENuS EVI2 time series (July 2018-June 2020) in a 5m pixel.

4. Monitoring Phenology using VIIRS EVI2

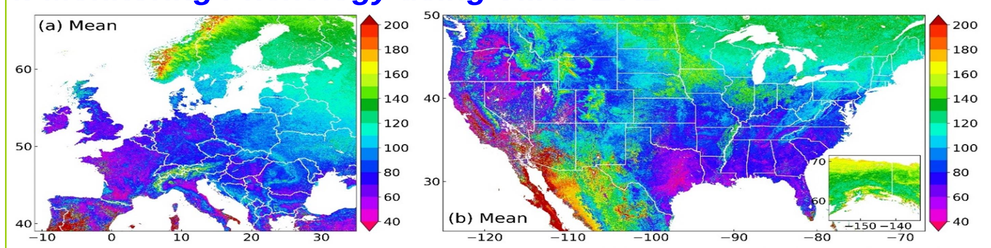


Fig 7. Mean VIIRS greenup onset (VNP22Q2 C1) from 2013–2020 in Europe (a) and the USA (b). The sub-window embedded in (b) is Alaska.

5. Validating VIIRS Phenology (VNP22Q2 C1) using species-specific in-situ observations

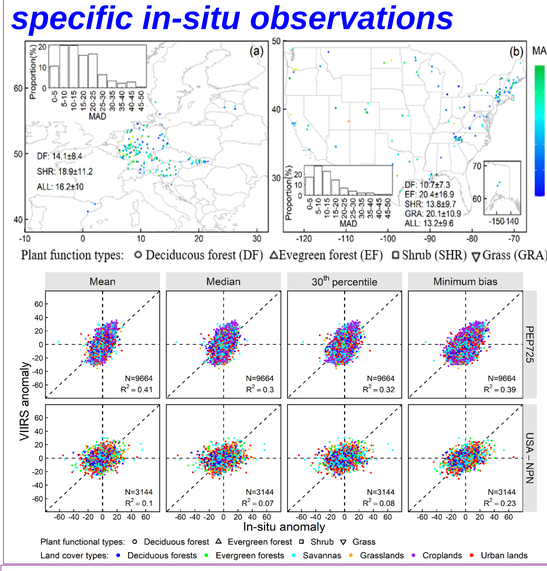


Fig. 8. Difference between VIIRS greenup onset and in-situ SOS during 2013–2020 in Europe (a) and the USA (b). Each VIIRS pixel contains more than 3 in-situ observations. MAD is mean absolute difference.

Fig. 9. Comparison of anomaly between VIIRS greenup onset and in-situ SOS during 2013–2020) in Europe and the USA, where the in-situ observations were aggregated using four different methods.

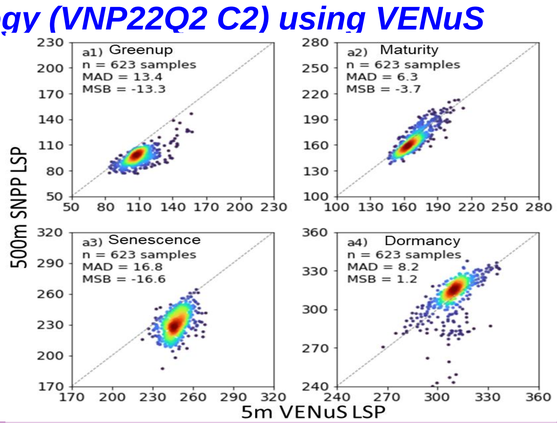
6. Validating VIIRS Phenology (VNP22Q2 C2) using HLS-PhenoCam detections

Table 1. Comparison of 30 m HLS-PhenoCam phenometrics with the NASA 500m VIIRS LSP products (VNP22Q2 C2) from SNPP and NOAA-20 during 2019 and 2020. VIIRS tiles (H12V04, H11V04, and H10V05) are indicated in **Fig. 5**. MAD-mean absolute difference (day).

		H12V04			
		Greenup	Maturity	Senescence	Dormancy
SNPP	MAD	7.1	3.7	21.3	4.2
	Bias	-5.9	0.6	-21.3	-0.7
NOAA20	MAD	5.5	3.4	22.0	4.2
	Bias	-4.4	-1.1	-22.0	-1.0
		H11V04			
		Greenup	Maturity	Senescence	Dormancy
SNPP	MAD	9.5	4.4	12.8	5.5
	Bias	-8.3	-2.3	-12.5	0.1
NOAA20	MAD	9.7	4.6	13.7	5.6
	Bias	-8.2	-3.1	-13.7	2.5
		H10V05			
		Greenup	Maturity	Senescence	Dormancy
SNPP	MAD	9.7	11.9	17.2	14.7
	Bias	-7.1	10.7	-17.0	-10.1
NOAA20	MAD	10.1	10.5	18.9	15.1
	Bias	-7.4	9.0	-18.9	-10.3

7. Validating VIIRS Phenology (VNP22Q2 C2) using VENuS VM1 Phenometrics

Fig. 10. Comparison between SNPP VIIRS and VENuS phenology detections for 2019 in the central USA (Fig. 6). Note that VENus time series surfers from cloud contaminations.



8. Conclusions

VIIRS greenup onset has a mean absolute difference of 14 days in comparison with species specific phenology from PEP725 observations and 12 days with USA-NPN observations although their spatial mismatch is a big concern. Further, the interannual comparison reveals that VIIRS greenup onset exhibits the same directions of multi-year anomalies and long-term trends as those of both PEP725 SOS and USA-NPN SOS over 70% of sample sites.

Fusion of 30m HLS data with field-based PhenoCam time series (HLS-PhenoCam) provides gap-free time series for generating reference dataset of phenology. This reference dataset is scalable to any spatial resolutions, and optimal for validating VIIRS LSP products. Compared with HLS-PhenoCam phenometrics, VIIRS LSP product (VNP22Q2 C2) from both SNPP and NOAA-20 generally shows a difference less than 10 days. Further, 500m VIIRS phenometrics also present a good agreement with 5m VENuS observations that are affected by clouds.