Questions & Answers Session 3

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Amber McCullum (amberjean.mccullum@nasa.gov) or Juan Torres-Pérez (juan.l.torresperez@nasa.gov).

Question 1: The SOS , MOS and EOS are produced on a yearly basis (phenology viewer). How do you deal with the regions having two growing seasons (summer crops and winter crops)? I think such regions should have two SOS, MOS and EOS.
Answer 1: Yes, the metrics used and the timing of those metics will depend on your ecosystem or agricultural system in this case. So you could have multiple SOS for example in these regions. The USGS, however in the Phenology Viewer only identifies one SOS for example per year. They do have some information about double-crop NDVI studies here: https://www.usgs.gov/land-resources/eros/phenology/science/challenges-deriving-phenological-metrics?qt-science_center_objects=0#qt-science_center_objects

Question 2: Could you recommend some smoothing method for NDVI time series?
Answer 2: Linear regression, spline smoothing, gaussian function fitting, are a few. For the USGS, they use a weighted, least-squares linear regression approach that involves a moving temporal window to calculate a regression line.

Here is an approach used by the USGS: https://www.usgs.gov/land-resources/eros/phenology/science/data-smoothing-reducing-noise-ndvi?qt-science_center_objects=0#qt-science_center_objects

Here is another paper that outlines some various smoothing techniques: https://www.mdpi.com/2072-4292/9/12/1271

Question 3: How to know the leaf expansion? using LAI? or just the peak of increase in photosynthesis?
Answer 3: Leaf Area Index (LAI) can be one technique used. You could compare the ground-based leaf expansion data from observations, to the satellite data (LAI, EVI, NDVI), as we showed with the case study examples.

Question 4: What is the "amplitude" in phenology?
Answer 4: The amplitude is the difference between Maximum NDVI (MAXN) and Start of Season NDVI (SONS). This is important to identify what increase of photosynthetic activity is relative to the baseline. This can be important for regions that never fully lose their leaves.

Question 5: Have you heard of the Hodrick-Prescott filter for noise reduction? If you have, does it improve on the analysis done on phenology data?
Answer 5: No, I am not familiar with that, but if you'd like to provide the reference to the group in the Q&A box we can ensure to pass that on to everyone else.

Question 6: There is a methodology to compare time series between different years? differences for long-term trends? for example NDVI max is not reached every year or NDVI min is lower in time every year?
Answer 6: Yes, we discussed these in the presentation. Threshold values are often used. For example, the threshold may be set at 0.1, and when the NDVI value reaches that point, the SOS is noted. This method can be effective for deriving the SOS in localized areas with relatively uniform land cover. But difficulties arise when using it to determine SOS over large areas with varying soil background characteristics or land cover types. In the United states this value generally varies from 0.08 to 0.04. Time series analysis is very important here.

Relative approaches can also be used: Relative approaches consider changes over multiple seasons to identify things like the SOS. This could be used when the pixel values are greater than the long-term mean or it could be a date prior to the annual mean (like 10 days for example).

Multi-year median NDVI can also be used to eliminate the impact of extremely high or low NDVI values. You can do this process first or after some type of filtering to reduce noise, but the benefit of this is that you can monitor individual pixels if that is of interest to tie those pixels to ground information.

Question 7: How can these methods be applied to perennial crops in tropical areas, where changes in canopies are not as marked as in temperate zones?
Answer 7: This is a great question, as the "greenness" of plants in tropical zones may not change much throughout the year. This is not a research area I have studied myself, but seasonality of GPP could be used alongside EVI, which is more sensitive to

changes in vegetation health in regions with high biomass (such as the tropics). Here is a paper where the researchers studied phenology in an Amazon floodplain forest: https://www.mdpi.com/2072-4292/11/13/1530.

Also, tropical forests are often covered by clouds, so SAR data may be of interest. Here is a special issue focused on remote sensing phenology in tropical forests: https://www.mdpi.com/journal/remotesensing/special_issues/Tropical_Phenology

You can also check out our SAR for forest mapping training: https://arset.gsfc.nasa.gov/land/webinars/forest-mapping-sar

Question 8: Is there any rule to decide the target wavelengths for NDVI calculation? For example, some researchers use 647-nm as Red and 857-nm as NIR, but some apply 680-nm as Red and 800-nm as NIR. Could you explain whether there is a specific rule to select the appropriate wavelength for NDVI and other vegetation indices?
Answer 8: I am not sure, it may just depend on the wavelength range of the sensor you are using as well. For Landsat, the NIR is 845-885 and the R is 630-680. But for MODIS these wavelength ranges are smaller than Landsat for the bands. Here are the wavelength ranges for MODIS: https://eos.com/modis-mcd43a4/

Question 9: Also, some researchers averages the reflectance values over the specific range of wavelength before calculating the vegetation index, but some calculate index for each wavelength, and then later average the index for the target wavelength. Which one is the recommended mean?
Answer 9: Again, this might depend on the sensor you are using. I would recommend the latter for Landsat for example, where the wavelength range is wider. However, if you are using hyperspectral sensors, the former may be a better approach.

Question 10: How do you eliminate cloud impact on NDVI?
Answer 10: You will need to do some multi-day composites to find a “good” pixel without clouds, or removal of the pixels with clouds entirely using a cloud mask. This is a real issue in tropical regions of high cloud cover. Composite images should not extend out too far for the dates so you do not miss any phenological events.

Question 11: What other methods of LSP can be adopted for evaluation outside the USA?

Answer 11: Similar approaches using the global phenology products discussed in session one can be used. For example, NDVI or EVI can be calculated across many ecosystems globally.

Question 12: Is the Growing Degree Days (GDD) significant to crop growth for the tropical countries which are high-temperature areas?
Answer 12: GDD is generally more useful in temperate regions, however, the baseline GDD can be modified based on the region.

Question 13: I do analysis mostly on landscape level it's pattern change. Does phenological study play a role in this or not? If yes, kindly explain? And also which kind of data will be useful for this?
Answer 13: This addresses the different scales of data. It will depend on the region of interest. If the area is small, other platforms (airborne, drones, commercial data) may provide data with higher spatial resolution.

Question 14: Which Vegetation index could be sensitive for forest evergreen in tropical areas when NDVI is not too sensitive?
Answer 14: EVI is a good option. NDVI tends to saturate at high biomass regions (tropical).

Question 15: Phenology, for the natural forest, is a vital tool to detect seasonality (SOS and EOS), but do controls such as Input used, Soil moisture and rainfall, Seed variety have to be considered for assessing the crop phenology?
Answer 15: Yes, I would say that the drivers of phenology are also very important to consider, things like temperature and precipitation anomalies will greatly impact the timing of phenological events.

Question 16: What are considered the best sensor for phonological sensing for (a) for areas with diverse leaf colors (blue, purple, yellow ets) vegetation area; and (b) an area dominant away for the usual green vegetation (possibly artificial or Parks and gardens) when using the NDVI?
Answer 16: For regions that are more heterogeneous, ground based or near surface data may be more useful. In order to use current NASA data, you need a larger region that is generally homogeneous. However, plants that are healthy will still reflect highly in the near infrared, that is why it is often used instead of the green band, so some of the standard indices can still be used.

Question 17: When is it best to consider using the SAVI without compromising the result since soil moisture or the variation in weather/season could influence received signatures?
Answer 17: SAVI is best used where there is a high percentage of bare ground cover. You could also compare SAVI values alongside NDMI (normalized difference moisture index) or actual soil moisture estimates (SMAP via NASA or ground-based data) to see how the soil moisture or the moisture content within the plants could influence the SAVI values.

Question 18: In slide number 30 what is the Y axis corresponding to? NDVI values?
Answer 18: This is the proportion of individuals with “yes” indicated in the observation record. So in slide 30, it is the proportion of Acer in red, Oak in green, and poplar in yellow that were indicated as scenessing during that specific date (x-axis).

Question 19: How easy is it to notice signatures of diseased or infectious vegetation cover using satellite sensors without ground validation?
Answer 19: It depends on the extent of the disease and the manifestation of the disease in the plants. For example, mountain pine beetle infestation can clearly be mapped using Landsat, for example because in the Sierra and the Rockies it is quite extensive, and it causes the trees to turn red, and the greenness to die down, so that can be seen in the satellite imagery

Question 20: Why poplars, maples, and oaks?
Answer 20: I believe these were selected because they are common, widespread across the country, and have clear phenophase transitions. They are also often used for tracking pollen for allergies and for wildfire risks in many parts of the country.

Question 21: Is NPN available for the entire word or just for the USA?
Answer 21: Unfortunately, NPN is only available to the USA.

Question 22: 'Butea monosperma' is a tree species characterized by orange to red flowers, which often cover the tree over leaves. How can you detect the SOS and EOS for such trees, and can NDVi be used for such tree species’ which do not show the appearance of many leaves but flowers?
Answer 22: One major factor to consider first, is that for this specific tree species, the use of NASA remote sensing data will require a fairly large homogenous region with

this species cover. As opposed to the NDVI, you may also use the NDMI, which estimates the moisture content of vegetation as opposed to the greenness. Changes in the moisture content may be related to flowering events. You should also compare ground-based observations of these phenophases alongside the remote sensing data to see if you are able to spot any patterns. You may actually see spikes in NDVI as the flowers may also reflect highly in the near-infrared. I am not familiar with this particular species to know if that may be the case. Here is a paper where the researchers used NDWI (similar to NDMI) to identify foliation changes in plants: https://www.sciencedirect.com/science/article/pii/S0034425715000218

Question 23: What preprocessing steps are required for Phenocam photographs before actual analysis?
Answer 23: I believe Phenocam has some quality control filters, such as too light or too dark, and a solar elevation filter applied. Here is more information about those filters and the processing you many need to take into consideration: https://daac.ornl.gov/VEGETATION/guides/PhenoCam_V1.html

Question 24: How we can find biomass and yield from satellite data?
Answer 24: Biomass estimation using remote sensing can be complex and often require validation of biomass estimates using ground based data. Many of these methods include vegetation models and radiative transfer models. Also, lidar data are often used for these types of estimates. The SAR handbook has a chapter devoted to biomass estimation: https://disasters.nasa.gov/news/servir-releases-sar-handbook

Question 25: Do the PhenoCam data need georectification of any sort, considering the angle of acquisition of Nadir looks more oblique for the slides shown in this presentation?
Answer 25: There are some pre-processing techniques that are done with PhenoCam data. Here is more information about those filters and the processing you many need to take into consideration: https://daac.ornl.gov/VEGETATION/guides/PhenoCam_V1.html

Question 26: Is it valid to use a mobile RGB camera with varying focal lengths for creating Phenocam Vegetation Indices?
Answer 26: I believe the PhenoCam cameras need to be stationary in order to take systematic measurements and to ensure that the images are taken over the same area

over time. Introducing mobile data collection would probably lead to a variety of other issues with georectification.

Question 27: Can remote sensing phenology be useful on large extents (like= million sq km) which are composite of different systems?
Answer 27: Yes, much of the NASA data are used for large regions. You may observe differences in the timing of green-up for different systems.

Question 28: How do you keep track of pheno reports over the years especially since you can't always expect the first phenophase to appear by all means after January? I refer to years of warm winters (dec-feb over northern hemisphere) that can trigger first phenophase in, say, mid December of the previous year but it makes sense that data belongs to the year starting with Jan. So, how do you easily browse through years/obtain data from the database for a certain year but when data may be found in the year before as well, but not always?
Answer 28: I am not sure which data platform you are referring to. But for the USGS Phenology Viewer that we discussed today, I believe you can search for multiple years and download the data for the year or years of interest.

Question 29: Could PhenoCam differentiate between vegetation in the Niger Delta region with rainy and dry with less seasonal distinction?
Answer 29: I am not familiar with the vegetation community in the Niger Delta, but you can use the PhenoCam Map Viewer to see if there are sites in that region. Generally, precipitation is a driver for greenness in vegetation, and therefore the indices outlined here should be useful to explore the phenophase shifts of vegetation in regions with pronounced wet and dry seasons.

Question 30: Does Phenocam help predict the possible date of sowing?
Answer 30: If it is a managed system, PhenoCam will obtain images when planting occurs. If you obtain PhenoCam images over the course of multiple years, you may be able to make some estimates of future planting. However, PhenoCam does not include forecast modeling.

Question 31: What are the measures for monitoring phenology of Evergreen vegetation?

Answer 31: Phenology patterns are more difficult to study in Evergreens. Here is a paper from 2016 that outlines a different index via MODIS data for these systems: https://www.pnas.org/content/pnas/113/46/13087.full.pdf

Question 32: PhenoCam derived indices, I see one potential problem in this method. When a camera is used to capture a wide range of canopy, distance may greatly affect the colors observed by it, possibly offsetting RGB values, hence affecting the indices. How do we go about this problem?
Answer 32: That is a good question, I am not sure how they deal with these potential issues. Here is more information about those filters and the processing you many need to take into consideration:
https://daac.ornl.gov/VEGETATION/guides/PhenoCam_V1.html

Question 33: Could the full data from the paper by Zhang et. 2018? since the link to the article found in the PDF of session 3 does not work.
Answer 33: Here is the link to the paper online:
https://www.sciencedirect.com/science/article/pii/S016819231830087X
We cannot provide you direct access to journals.

Question 34: As most of the field crops and fruit crops often prone to pest and disease attacks, is phenocam has any module to predict such challenges?
Answer 34: Remote sensing imagery can be used to identify disease, and Phenocam data could be used in the same manner. But it depends on the extent of the disease and the manifestation of the disease in the plants. For example, mountain pine beetle infestation can clearly be mapped using Landsat, for example because in the Sierra and the Rockies it is quite extensive, and it causes the trees to turn red, and the greenness to die down, so that can be seen in the satellite imagery. There are no specific models for PhenoCam, it is just the imagery data available.

Question 35: There is an important topic of "Tree-line Shifting to higher Altitudes" in the Himalayas. Any similar phenomenon in the US?
Answer 35: Yes, I believe this has also been observed in the Sierra Nevada. Here is a paper that may be of interest:
https://www.researchgate.net/publication/318680182_Climate_Change_and_Tree-line_Ecosystems_in_the_Sierra_Nevada_Habitat_Suitability_Modeling_to_Inform_High-elevation_Forest_Dynamics_Monitoring

Question 36: In slide 45, you mention that the plants in urban zones changed their phenology according to the temperature that UHI produces. However, do you know or is it possible to suggest that the excessive temperature can cause mutation to the plants, I mean, transformation of the leaves of the plants to thorns in order not to lose water?
Answer 36: I am sure this is possible, but was not a topic covered in the case-study example I provided.

Question 37: Can you say more about what is missed from the data with the veg index calculated with PhenoCam data? Beyond that NIR is missing.
Answer 37: The absence of the Near Infrared band is the primary reason for using a different index for the PhenoCam data, as the other indices like NDVI use the NIR. However, at many sites, the PhenoCam images include NIR, so you would just need to check the specific site of interest.

Question 38: How is the NDVI threshold calculated?
Answer 38: There are many different methods for determining the threshold values. For delineating the SOS, threshold values are often used. This can be done with a predefined threshold approach, For example, the threshold may be set at 0.1, and when the NDVI value reaches that point, the SOS is noted. This method can be effective for deriving the SOS in localized areas with relatively uniform land cover. But difficulties arise when using it to determine SOS over large areas with varying soil background characteristics or land cover types. In the United states this value generally varies from 0.08 to 0.04.

Relative approaches consider changes over multiple seasons to identify things like the SOS. This could be used when the pixel values are greater than the long-term mean or it could be a date prior to the annual mean (like 10 days for example).

Question 39: How can we download data on phenology for every country? Is it possible?
Answer 39: Most of the networks discussed in this training focused on US based networks (except for PhenoCam), but there may be other networks globally that I am not familiar with.

Question 40: What are the physical mechanism(s) by which population density (as opposed to UHI temperature) is/are thought to advance/delay phenological indicators? e.g., aerosol optical depth, urban shading...
Answer 40: Air quality could also be a factor, I believe in the case study presented the researchers only took into account temperature. You can find more information here: https://www.nature.com/articles/s41559-019-1004-1

Question 41: Can we map the phenology of plants with SAR data?
Answer 41: Yes, the structure and water content of plants, as linked to phenophase shifts, can be mapped with SAR data. There are many papers on this, here are a few resources:

- https://www.sciencedirect.com/science/article/pii/S0034425717303450
- https://www.spiedigitallibrary.org/conference-proceedings-of-spie/11149/1114903/Evaluation-of-Sentinel-1-and--2-time-series-to/10.1117/12.2533132.full?SSO=1

Question 42: Are there necessary corrections applied before PhenoCam vegetation indices could be computed?
Answer 42: Here is more information about those filters and pre-processing for PhenoCam: https://daac.ornl.gov/VEGETATION/guides/PhenoCam_V1.html

Question 43: Working for phenology study in a mountainous area having many issues like cloud, snow, shadow, and terrain. What do you suggest about phenology study in these areas, what indices, the filter is useful in areas?
Answer 43: I would suggest the use of SAR data in regions where clouds are often seen. Also, higher spatial resolution data may be needed in complex terrains in high elevations, so commercial satellites may be another option to explore.

Question 44: Do you have any suggested considerations/cautions for using distinctions in NDVI time series curves by Landsat pixel as a way to classify different vegetation types (say early summer growth vs late summer growth)?
Answer 44: It would probably depend on if there are any distinct differences in the growth patterns and vegetation health during these different times throughout the season. Also, the spatial scale is always something to consider.

Question 45: i) In places where the ground truth system has not been developed like the US, which ground-based methods can be used to verify the remote sensing data, it

leaves only. ii) in the calculation of NDVI, how do you evaluate the correctness in the NDVI calculation (not using ground truth method)? Is the NDVI calculation still valid if each time you calculate on the same Landsat image, bands come out with slightly different numbers?
Answer 45: Ground truthing is really the only way to accurately validate your remote sensing data. Some folks have used higher resolution imagery (commercial satellites) to validate land cover types as well. When calculating NDVI, it is important to conduct all the preprocessing steps on the Landsat image (atmospheric correction, etc.) to ensure your multi-image analysis is similar over time. You can obtain the Spectral Reflectance products now for Landsat where most of these steps are already applied. There will be some differences in the data from various Landsat sensors too (from 5 to 8), so that is another consideration.

Question 46: Have you seen research that combines or compares NDVI and SAR data curves to have the SAR data fill the data gaps of NDVI in cloudy regions?
Answer 46: Yes, here is a paper that used Sentinel-1 (SAR) with Sentinel-2 (optical) to look at plant phenology: https://www.spiedigitallibrary.org/conference-proceedings-of-spie/10783/1078304/Using-Sentinel-1-SAR-data-for-crop-phenological-development-monitoring/10.1117/12.2325715.full