USA National Phenology Network

USA National Phenology Network Data Product Development Framework and Data Product Catalog, v 1.1

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EXECUTIVE SUMMARY

The goals of the USA National Phenology Network (USA-NPN, www.usanpn.org) are to advance science, inform decisions, and communicate and connect about the field of phenology and the responses of species to environmental variation and climate change (USA-NPN 2016). The USA-NPN seeks to facilitate informed ecosystem stewardship and management by providing phenological data and information freely and openly. This report describes the current state of the USA-NPN's data product development and data quality assessment to support the analysis and application of the phenological data and information maintained by the organization. These derived phenology data products will support informed decision making via the creation of dynamic, predictive models that provide short-term (days) and eventually longer-term (months and years) forecasts of phenological activity based on climatic conditions. We present the process by which the National Coordinating Office (NCO) of the USA-NPN will advance the organizations strategic goals by selecting, prioritizing, developing and delivering data products over the next 5 years.

BACKGROUND

The USA National Phenology Network supports the advancement of science and decision-making in many sectors by creating, maintaining, and sharing data, data products, and decision-support tools; designing and maintaining monitoring protocols and information management systems; creating partnerships; facilitating research; and communicating the value of phenology to many audiences. The USA-NPN serves not only as a data repository, but also as a hub of phenology-related activities for researchers, practitioners, decision-makers, and the public. The data, data products and information collected, created, and maintained by the USA-NPN support the needs of multiple stakeholder groups including, but not limited to, federal agency partners (including DOI bureaus), academic researchers, policy makers, educators, and community organizations.

Since the establishment of the USA-NPN in 2007, several key activities have shaped and refined the plans for data products offered by the USA-NPN. In May 2012, the USA-NPN National Coordinating Office (NCO) and the former USA-NPN Advisory Committee convened a NSF-funded Research Coordination Network workshop in Milwaukee, Wisconsin (USA-NPN 2012). The goal of the workshop was to identify linkages between grand challenges in the field of phenology and the data requirements and data products necessary to address those challenges. Forty-five academic and agency scientists with interest in the analysis and application of phenology data for management and science attended the two-day workshop which set the framework for the USA-NPN National Coordinating Office to begin describing and prioritizing phenology data products derived from in-situ observation data.

In 2014, a USGS program review of the USA-NPN recommended that the NCO further prioritize the development and delivery of high quality data products. Subsequently, the NCO convened an internal Data Product Working Group to prioritize, describe, develop and deliver phenology data products. As a result, the NCO created the first version of the data product catalog, released in April 2015, to communicate our framework for planned and current products. This document is aligned with the USA-NPN Strategic Plan; the focus of product development is to achieve the organizational goals of advancing science in the field of phenology and informing decisions related to how species are responding to environmental variation and climate change. Since the Data Product Working Group was established, the NCO has developed and released numerous products and tools,

including phenology calendars, summarized in-situ data, in-situ data integrated with climate data, a re-designed visualization tool and phenology observation portal, and two suites of historical and contemporary gridded products based on the Spring Indices (Schwartz et al. 2013, Ault et al. 2015) and accumulated growing degree days. Most recently, external academic researchers with expertise in phenology model development participated in a March, 2016 workshop convened by the NCO, with the goal of converging on a strategy for developing the next generation of predictive phenology models. The NCO will continue to engage with stakeholder audiences to further define needed data products and access tools, as well as subject-matter experts to support the development of these resources.

This document describes the current state of the USA-NPN's data product development and data quality assessment as well as the process for selecting, prioritizing, developing and delivering data products over the next 5 years. The USA-NPN NCO develops and delivers value-added phenology data products to advance science, inform decisions, and communicate the value of phenology and related information (USA-NPN 2016). We are currently scoping, vetting, developing, and delivering many of the products described in this document, with additional products scheduled to be delivered in the next 1 to 3 years. Selected data products will be developed in-house by the NCO, and others will result from collaborations with our stakeholders and members of the broader phenology community to capitalize on a wide range of skills and expertise. Ultimately, we envision that these products will support an extensive array of applications that will further advance our understanding of phenology and our ability to respond and adapt to climate change.

DATA PRODUCT CLASSIFICATION

The NCO's Data Product Working Group oversees the prioritization and development of high priority data products that could be derived from the NPDb and/or other data streams. The NCO Data Product Working Group, organized products in broad data product suites, characterized by the structure and required data streams of the associated products. Within each data product suite (Figure 1), we identified related products (Table 2) that accounted for the ecological, spatial, and temporal scale of interest of prospective data users (e.g., phenometrics will be delivered for individual organisms, as well as for sites and regions). Additional details for each data product are contained within a Data Product Catalog (Table 3).

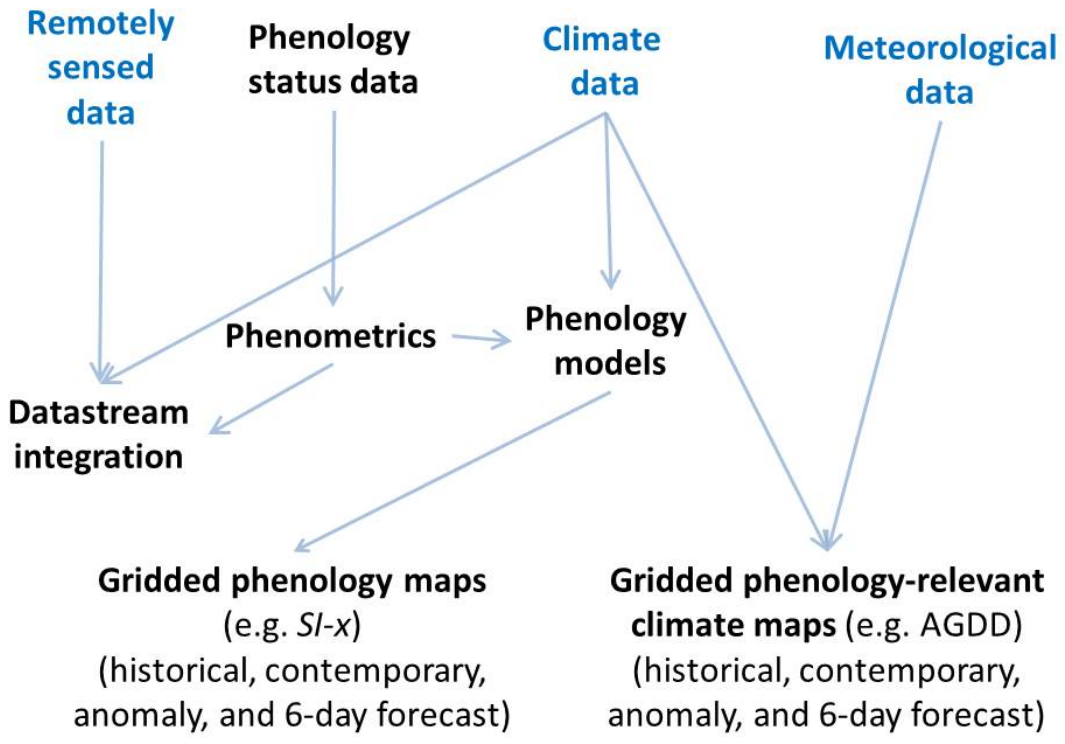

Figure 1: Relationships between data product suites (stand-alone components of the chart shown in black or blue) demonstrating how each suite provides a foundation for, or is used to derive, other suites of products. Definitions of data product suites are in Table 2, and detailed information about products and sub-products are in Table 3. All data derived from the National Phenology Database (NPDb) is represented in black text, and ancillary data sources are represented in blue text.

DATA PRODUCT DELIVERY

Data products are shared through a range of appropriate tools (Table 1). The primary audiences vary by tool, and include scientists, including ecologists; natural resource managers; climate scientists and modelers.

Table 1: USA-NPN data delivery tools.

Data Delivery Tool	**Data product(s)**	**Tool launch date**
Phenology Observation Portal (www.usanpn.org/results/data)	Phenophase status and intensity data; individual phenometric; Site phenometrics	2011
SOAP and REST API	Phenophase status and intensity data; individual phenometric; Site phenometrics	2014
Phenology Data Visualization Tool (www.usanpn.org/data/visualizations)	Phenophase status and intensity data; individual phenometric; gridded phenology and climate maps; gridded land surface phenology (LSP) derived phenology products (coming 2018)	2015
OGC Webservices	Gridded phenology and climate maps	2016
Geoserver Request Builder (www.usanpn.org/geoserver-request-builder)	Gridded phenology and climate maps	2016

Table 2: USA-NPN Data Product Overview, including stage of development and the proposed delivery date. Data products are nested within Data Product Suites, as shown in Figure 1. Data products are differentiated by ecological and spatial scale.

Data Product Suite	Suite description	Example application	Data Product Number and Name	Ecological Scale	Spatial Scale	Short Product Description	Stage of development	Proposed delivery timeline
A. Phenophase Status Data	Presence and absence of phenophase activity for plants and animals based on *in-situ* observations	Validating phenology models based on remotely-sensed data	**A1**. Status and intensity data with QC flags	Individual[a]	Site[c]	Status and intensity data with ancillary site, plant, protocol and observer information	Available	Available
B. Phenometrics	Estimates of onset, end and peak dates of phenophase activity for multiple spatial scales	Characterizing the inter-annual variability in growing season onset and length between bioregions across the continent.	**B1**. Individual phenometrics with QC flags	Individual	Site	Phenophase start and end dates on individual organisms	Available	Available
			B2. Individual phenometric peak intensity curves	Individual	Site	Estimates of peak magnitude or intensity	Scoping	2017

Data Product Suite	Suite description	Example application	Data Product Number and Name	Ecological Scale	Spatial Scale	Short Product Description	Stage of development	Proposed delivery timeline
B. Phenometrics	Estimates of onset, end and peak dates of phenophase activity for multiple spatial scales	Characterizing the inter-annual variability in growing season onset and length between bioregions across the continent.	**B3.** Site Phenometrics with QC flags	Species	Site to region	Estimates of mean phenophase onset, peak, duration and end with variance	Available	2016
			B4. Growing season onset, duration and end	Functional group[b] (e.g. deciduous trees)	Site to region	Estimates of site to regional mean phenophase onset, peak, duration and end dates with variance	Scoping	2017
			B5. Simple phenology calendar	Individual	Site	Simple visualization of phenological activity patterns of individual organisms at a site	Available	2015
			B6. Advanced phenology calendar	Species to functional group	Site	Annual pattern of phenometric activity (onset, duration, and end) calculated and displayed in a chart at the site or regional level	Available	2015
			B7. Advanced phenology calendar with phenophase magnitude	Species to community[d] to functional group	Region	Annual pattern of phenometric activity, including intensity peak curves, displayed in a chart at the site or regional level	Visioning	2018

Data Product Suite	Suite description	Example application	Data Product Number and Name	Ecological Scale	Spatial Scale	Short Product Description	Stage of development	Proposed delivery timeline
C. Species responsiveness	Quantifying phenological variability in relation to climatic variation	Research to link responsiveness to demography or distributions; phenological information used in vulnerability assessments in protected areas	**C1.** Site-level species responsiveness	Species	Site	Database of estimated phenological trait variation with key climatic drivers (e.g. temperature and precipitation) for individuals at sites that have been monitored multiple years	Visioning	2017
			C2. Integrated species responsiveness	Species	Region	Database of climatic responsiveness estimates integrated across sites to generate species- level metrics of phenological plasticity	Visioning	2017
D. Phenology models	Models that link historical, current or future climatological information with phenometrics	Models used as a national indicator of climate change by federal agencies (e.g. EPA); Investigation of the climatic drivers leading to the initiation of Spring	**D1**. Extended Spring indices (SI-x; leaf and bloom)	Species (ornamental shrubs[d])	Continent	Species-specific mathematical models that predict phenometrics based on climatic drivers for select taxa	Available	Available
			D2. Lilac and honeysuckle phenophase algorithms	Species (ornamental shrubs[d])	Continent		Available	Available
			D3. Individual native taxa phenophase algorithms	Species	Region to continent		Scoping	2017
			D3. Data-model fusion	Species to functional group	Region to continent	Dynamic models couple existing phenology static models with incoming quality controlled raw and derived data	Visioning	2018

Data Product Suite	Suite description	Example application	Data Product Number and Name	Ecological Scale	Spatial Scale	Short Product Description	Stage of development	Proposed delivery timeline
E. Gridded phenology maps	Gridded historical and forecast maps; Use of phenology data and models to visualize past, current and future predicted phenological patterns	Maps and associated products will inform planning and adaptation for future climate change scenarios; Development of tools that predict when to expect leaf-out or flowering at a specific site in a given year, given current climatic conditions	**E1**. Gridded historical maps (1981-2015)	Species to functional group	Continent	Retrospective phenology modeling using historical gridded climatological data	Available from 1981-present (*SI-x*); Scoping (*non-lilac species*); Scoping 1900-1980 (*SI-x*)	2016+
			E2. Gridded long-term average maps (1981-2010)	Species to functional group	Continent	Average historical conditions	Available (*SI-x*); Scoping (*non-lilac species*)	2016+
			E3. Gridded anomaly maps	Species to functional group	Continent	Comparison of contemporary modeling to 30 year average	Available (*SI-x*); Scoping (*non-lilac species*)	2016+
			E4. Gridded daily model output (current year, up to current day and 1-6 day forecast maps)	Species to functional group	Continent	Phenology models are gridded using current weather data	Available (*SI-x*); Scoping (*non-lilac species*)	2016+
			E5. Gridded projection maps (2017-2100)	Species to functional group	Continent	Phenology models are gridded using climate projections (decadal) for regional climatology	Scoping	2017

Data Product Suite	Suite description	Example application	Data Product Number and Name	Ecological Scale	Spatial Scale	Short Product Description	Stage of development	Proposed delivery timeline
E. Gridded phenology maps	Gridded historical and forecast maps; Use of phenology data and models to visualize past, current, and future predicted phenological patterns	[See above]	**E6**. Gridded LSP products	Functional group	Continent	LSP metrics for the day of year corresponding to the start of spring (SOS) and end of fall (EOF), as well as the growing season length based on the SOS and EOF.	Scoping	2017
F. Gridded climate maps	Gridded phenology-relevant climate maps; Use of temperature accumulation to predict phenological patterns	Predict frost and pest risk to crop species for which accumulated growing degree thresholds are known	**F1-F4:** parallel products to E2-E6 for Accumulated Growing Degree Days	Species	Continent	See E1-E5	Available (F1-F4); Scoping (F5)	2016
			F5. Known AGDD threshold to onset DOY conversion	Species	Continent	Allow data users to input known species threshold AGDD values to generate DOY maps that represent phenophase onset DOY	Visioning	2017
			F6. Interactive AGDD map generation	Species	Continent	Manipulate start and end date for accumulations, set base temperatures, and set known species-specific threshold	Visioning	2017

Data Product Suite	Suite description	Example application	Data Product Number and Name	Ecological Scale	Spatial Scale	Short Product Description	Stage of development	Proposed delivery timeline
G. Datastream Integration	Integrate and deliver phenology information from disparate scales and platforms, e.g., in-situ, near-remote sensing (camera-based, UAV), and far remote sensing (satellite-based)	*In-situ* data is used to calibrate and validate land-surface phenology from satellite imagery; regional phenometric data used to compare start of season from ground to satellite	**G1.** Climate-*in situ* integration	Species	Site	Daily climate data extracted for and delivered with site-level phenometric data.	Available	2016
			G2. Phenocam-*in situ* integration	Species to community to functional group	Site	Delivery of integrated camera data and *in situ* data	Visioning	2018
			G3. Satellite-*in situ* integration	Functional group to community	Region to continent	Delivery of integrated satellite data and *in situ* data	Scoping	2017

[a]Individual organism, or, in the case of animals, a species record at a given site.
[b]Functional group, e.g. deciduous trees. Collections of organisms based on morphological, physiological or behavioral characteristics.
[c]Site is a georeferenced location in a relatively uniform habitat where one or more individual(s) of one or more species are being monitored.
[d]Community is an assemblage of two or more species occupying the same geographic area.
[e]Cloned lilac, common lilacs, and honeysuckles have been tracked for over 60 years (Schwartz et al. 2012). These observations allow scientists to determine when differences in the timing of phenological events between individuals are due to differences in local environmental condition

DATA PRODUCT CATALOG

Table 3 below contains a detailed description of all data products (as summarized in Table 2) within each data product suite (Figure 1). These descriptions contain identities of subproducts as well as product delivery method. Subproducts are customizations within data products that focus on a particular region, species, or phenophase to address specific science, management, and stakeholder needs. User-defined customizations (e.g., selecting specific species or phenophases of interest using the Phenology Observation Portal) are not considered subproducts within this catalog framework.

Table 3. USA-NPN Data Product Catalog

Product identification number:	A1
Product suite:	Phenophase Status Data
Product name:	Phenophase Status and Intensity Data
Subproduct name(s):	*Nature's Notebook* Dataset (2009-present) Legacy Lilac and Honeysuckle Eastern and Western Datasets (1956-2008; Dataset IDs: 7 and 8 respectively)
Format:	Data are stored in MySQL database and made available in CSV format
Ecological scale:	Individual organism (plants); Species at a site (animals)
Spatial scale:	Site
Short description:	All submitted status and intensity data in the NPDb. Includes ancillary site, plant, protocol and observer data.
Delivery method:	Phenology Observation Portal (www.usanpn.org/results/data) USA-NPN API
Relevant citations:	Denny et al. 2014
Quality Checks:	Data Quality Assurance and Quality Control Information Sheet
Data Processing & Scientific Workflows:	Beyond the quality checks, these data are not processed.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~2.4GB
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
Repository for Data:	Data stored at USA-NPN. Metadata for these data is stored in the USGS Science Data Catalog, Ecosystems.data.gov and Data.gov, ScienceBase and KNB.
Citation:	USA National Phenology Network. Year of dataset access. Dataset Name [Status and Intensity, Individual Phenometrics, or Site Phenometrics] Phenology Data for the United States, Date range of data used. USA-NPN, Tucson, Arizona, USA. Data set accessed YYYY-MM-DD at

	http://dx.doi.org/10.5066/F78S4N1V
Digital Object Identifier (DOI)/Link:	http://dx.doi.org/10.5066/F78S4N1V

Product Description:

Data are presented as phenophase status records for individual organisms (plants) or species (animals) at a site on a particular datetime, for a particular phenophase. Each phenophase record has a "0", "1" or "-1" status (observer has responded no, yes, or uncertain if the phenophase was observed on that individual on that datetime; Denny et al. 2014). In addition, records may be accompanied by intensity measurements to quantify the magnitude of occurrence of a phenophase for a given individual on a given datetime. Each record is associated with an individual observer in addition to a location (latitude, longitude, and elevation), date, and time. This dataset includes ancillary site, plant, protocol, and observer level data, and FGDC metadata. Data includes *Nature's Notebook* observations as well as data from other sources that have used compatible protocols and have been integrated into the NPDb. Data from each distinct source is considered a subproduct and may be filtered out from the combined dataset using the Dataset ID (e.g. Legacy Lilac and Honeysuckle Eastern and Western Datasets). Links to documentation for these data from other sources can be found in ancillary data. Data is currently available for download from the Phenology Observation Portal from the www.usanpn.org/results/data. Data downloads can be customized based on desired date fields, species, states, phenophases, and partner groups. As of October 2014, status and intensity data is presented with flagged records when there are (1) conflicts in phenophase status records from multiple observers on an individual organism on the same day, and (2) conflicts in phenophase status records from the same observer on an individual organism on the same day. Improbable latitude, longitude, and elevation values are corrected. Additional QC flags will be implemented as available and appropriate, including those outlined in the QA/QC section.

Product Identification Number:	B1
Product Suite:	Phenometrics
Product Name:	Individual Phenometrics
Subproduct(s):	Historical Lilac and honeysuckle dataset
Format:	Data are stored in MySQL database and made available in CSV format
Ecological Scale:	Individual organism (plants); Species at a site (animals)
Spatial Scale:	Site
Short Description:	Delivery of phenophase first and last observed phenophase dates, and durations
Delivery method:	Phenology Observation Portal (www.usanpn.org/results/data) USA-NPN API
Relevant Citations:	Rosemartin et al. 2015; http://dx.doi.org/ 10.5061/dryad.0262m
Quality Checks:	Data Quality Assurance and Quality Control Information Sheet
Data Processing & Scientific Workflows:	Described in Open File report, in prep.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~150MB
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
Repository for Data:	Data stored at USA-NPN, Dryad and ScienceBase. Metadata additionally published to USGS Science Data Catalog, Ecosystems.data.gov and Data.gov.
Citation:	USA National Phenology Network. Year of dataset access. Dataset Name [Status and Intensity, Individual Phenometrics, or Site Phenometrics] Phenology Data for the United States, Date range of data used. USA-NPN, Tucson, Arizona, USA. Data set accessed YYYY-MM-DD at http://dx.doi.org/10.5066/F78S4N1V Rosemartin AH, Denny EG, Weltzin JF, Marsh RL, Wilson BE, Mehdipoor H, Zurita-Milla R, Schwartz MD (2015) Lilac and honeysuckle phenology data 1956-2014. Scientific Data 2: 150038. http://dx.doi.org/10.1038/sdata.2015.38.
Digital Object Identifier (DOI)/Link:	http://dx.doi.org/10.5066/F78S4N1V

Product Description:

Each row of this dataset represents a series of consecutive "yes" phenophase status records, beginning with the date of the first "yes" and ending with the date of the last "yes" recorded for a given phenophase on a given organism for a specific time period selected by the data user. If a phenophase status of "no" was recorded prior to the first "yes" or after the last "yes", the gap (in days) between the "yes" and "no" records is also given. There may be multiple series (rows) for a given phenophase on a given organism

within the same year. This occurs in circumstances where there were multiple periods of activity throughout the year (i.e. reports of "yes" to a given phenophase on the organism interspersed with reports of "no"). This dataset includes ancillary site, plant, protocol, and observer data, and FGDC metadata. Data are available for download from the www.usanpn.org/results/data. Data downloads can be customized based on desired date fields, species, states, phenophases, year (e.g., water year or calendar year) and partner groups. Data have undergone QC procedures and flagging described in product A1. The Historical Lilac and honeysuckle dataset is comprised of lilac (*Syringa vulgaris* and *S. x chinensis* 'Red Rothomagensis') and honeysuckle (*Lonicera tartarica* 'Arnold Red' and *L. korolkowii* 'Zabeli') leaf and bloom data collected 1956-2014 across the continental United States (Schwartz et al., 2012, Rosemartin et al. 2015). The dataset combines historic event dates (e.g., "first" observed flowering) with contemporary, *Nature's Notebook* phenometric data, and is available within product A1 and B1.

Product Identification Number:	B2
Product Suite:	Phenometrics
Product Name:	Individual phenophase peak and curves
Ecological Scale:	Individual organism (plants); Species at a site (animals)
Spatial Scale:	Site
Short Description:	Estimates of peak intensity
Delivery method:	Phenology Observation Portal (www.usanpn.org/results/data)

Product Description:

"Peak" metrics of phenophase activity are potentially more biologically relevant or reliable than onset for ecological studies, particularly when drawing links between phenology and population level processes, performance, and species interactions (e.g. Miller-Rushing et al. 2008). For each period of phenophase activity for an individual organism (plants) or species (animals) at a site, this product delivers the mean and median dates of observed activity. Additionally, for individuals for which intensity data were collected during those periods, this dataset will include the date or range of dates for which the highest bin values for activity was observed as well as a peak date as determined by a curve fitted over intensity bin data. Ultimately these data will be delivered with summarized data providing first and last phenophase dates via the Phenology Observation Portal (www.usanpn.org/results/data), and as a visualization in the USA-NPN visualization tool (www.usanpn.org/data/visualizations).

Product Identification Number:	B3
Product Suite:	Phenometrics
Product Name:	Site Phenometrics
Subproduct Name:	N/A
Format:	Data are stored in MySQL database and made available in CSV format
Ecological Scale:	Species
Spatial Scale:	Site to region
Short Description:	Estimates of mean phenophase onset, peak and end dates with variance
Delivery method:	Phenology Observation Portal (www.usanpn.org/results/data) USA-NPN API
Relevant citations:	N/A
Quality Checks:	Data Quality Assurance and Quality Control Information Sheet
Data Processing & Scientific Workflows:	Described in Open File report, in prep.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~150MB
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
Repository for Data:	Data stored at USA-NPN. Metadata for these data is stored in the USGS Science Data Catalog, Ecosystems.data.gov and Data.gov, and ScienceBase.
Citation:	USA National Phenology Network. Year of dataset access. Dataset Name [Status and Intensity, Individual Phenometrics, or Site Phenometrics] Phenology Data for the United States, Date range of data used. USA-NPN, Tucson, Arizona, USA. Data set accessed YYYY-MM-DD at http://dx.doi.org/10.5066/F78S4N1V
Digital Object Identifier (DOI)/Link:	http://dx.doi.org/10.5066/F78S4N1V

Product Description:

Phenometric values are provided for a species at a site. These records include mean, variance, and sample size for onset and end dates for periods of phenophase activity of multiple individuals within a species in a given year for the site or region of interest. In circumstances where data users request mean values for multiple sites, means will be calculated based on site means rather than treating all individuals within a region as independent. Individuals included in data output will have to meet user-selected criteria for inclusion in estimates; specifically, only individuals with onset and end dates that are preceded or followed by a negative record either (a) ≤ 7 days, (b) ≤ 14 days, or (c) ≤ 30 days from the first and last observed positive records will be included (Gerst et al, 2015). If there are multiple transitions within the year of interest for a given phenophase, only the first onset and last end dates will be used for site-level calculations. Peak dates will be determined from individual mean activity dates during the period of interest. This dataset

includes ancillary site, plant, protocol, and observer data, and FGDC metadata. Data will be available for download from the Phenology Observation Portal (www.usanpn.org/results/data). Data downloads can be customized based on desired data fields, species, states, phenophases, and partner groups.

Product Identification Number:	B4
Product Suite:	Phenometrics
Product Name:	Growing season onset, duration and end
Subproduct Name(s):	NEON domain phenometrics, Protected area phenometrics, Ecoregion phenometrics, Pheno-region phenometrics
Ecological Scale:	Functional group
Spatial Scale:	Region
Short Description:	Estimates of site to regional mean phenophase onset, peak, duration and end dates with variance
Delivery method:	Static files available for download

Product Description:

Phenometric values are provided for regions that have been determined to be of distinct ecological and climatic interest to the data user community. These will include the regions delineated by protected areas (such as National Parks and National Wildlife Refuges), Ecoregions (e.g. Bailey's ecoregions, Bailey et al. 1994), NEON domains (http://www.neoninc.org/), and pheno-regions (e.g. Buitenwerf et al. 2015). These records include mean, variance, and sample size for onset, peak, duration, and end dates for periods of phenophase activity of multiple individuals and species in a given year for the region of interest. This product will include data for all deciduous tree and shrub taxa. Phenometrics will be calculated based on the "Breaking leaf buds", "Young leaves", "Leaves", and "Colored leaves" phenophases. Peak dates will be calculated based on the shape of the curves describing the proportion of individuals within sites reporting yes to a phenophase throughout the period of activity divided into two week increments. Growing season duration will combine multiple periods of activity within a year when relevant (e.g. for regions where drought deciduous taxa are common). Phenometric means will be calculated based on site means rather than treating all individuals within a region as independent. This dataset includes ancillary site, plant, protocol, and observer level data, and FGDC metadata.

Product Identification Number:	B5
Product Suite:	Phenometrics
Product Name:	Simple phenology calendar
Ecological Scale:	Individual
Spatial Scale:	Site
Short Description:	Simple visualization of phenological activity patterns of individual organisms at a site
Delivery method:	Observation Deck of *Nature's Notebook* observers

Product Description:

Phenology calendars allow for the simple visualization of the time period for which an organism was phenologically active. These customized graphs show *Nature's Notebook* observers the patterns within their own data. Calendars enable parks and protected areas to make management decisions based on the timing of active periods of species of interest, and to communicate with the timeframes that visitors can expect to see wildflowers and wildlife. Simple phenology calendars will deliver graphically displayed phenometric data from individual organisms on the Observation Deck of *Nature's Notebook* observers. The x-axis displays month and the y-axis can be customized to a specific individual organism/phenophase from the observer's own site and displays data for two user-selected years in the form of two color-coded horizontal bars for each selected phenological period. Source data is based on summarized individual-level phenometric start and end dates.

Product Identification Number:	B6
Product Suite:	Phenometrics
Product Name:	Advanced phenology calendar
Ecological Scale:	Species to Functional Group
Spatial Scale:	Site to region
Short Description:	Annual pattern of phenometric activity (onset, duration, and end) calculated and displayed in a chart at the site or regional level
Delivery method:	Dynamic phenology data visualization tool

Product Description:

Advanced Phenology calendars will summarize phenometric data across individuals either within a site or a user-defined region of interest. Data users can opt to summarize data for multiple species together (such as for all deciduous trees, treating species as replicates, which would visualize growing season length). The x-axis will be customized by the user to either display one user-defined year of interest or a generalization of all years combined. The y-axis will be customized to either include (1) one phenophase for multiple species, or (2) multiple phenophases for one species. Source data will be based on summarized mean site-level phenometric start and end dates with error bars representing variance among individual organisms and sites.

Product Identification Number:	B7
Product Suite:	Phenometrics
Product Name:	Advanced phenology calendar with phenophase magnitude
Subproduct(s):	Site- and regional-level synchrony curves
Ecological Scale:	Species to community to Functional Group
Spatial Scale:	Site to region
Short Description:	Annual pattern of phenometric activity, including intensity peak curves, displayed in a chart at the site or regional level.
Delivery method:	Dynamic phenology data visualization tool

Product Description:

Advanced phenology calendar with intensity will build upon the Advanced phenology calendars (Product B6) by including magnitude, intensity, and peak in the chart output. The y-axis will be limited to displaying one phenophase for one species or functional group for a site or region of interest; this will be represented by a horizontal bar showing the period of activity for one or multiple years. Above the horizontal bar will be a fitted curve representing the proportion of individuals within sites reporting yes to a phenophase throughout the period of activity. Source data will be based on summarized mean site-level phenometric start and end dates with error bars representing variance among individual organisms and sites.

Quantifying mismatch within species interactions, particularly mutualisms, has been identified as a critical element of understanding the ecological impacts of climate change on phenology (Miller-Rushing et al. 2010, Kudo 2013). These advanced calendars will have a secondary functionality (classified here as a subproduct) that will allow for the display, characterization, and quantification of phenophase overlap between two or more co-occurring species within a site or region. These "synchrony curves" will produce a metric of temporal overlap calculated from the normalized area underneath the phenophase curves described in the above paragraph.

Product Identification Number:	C1
Product Suite:	Species responsiveness
Product Name:	Site-level species responsiveness
Ecological Scale:	Species
Spatial Scale:	Site
Short Description:	Database of estimated phenological trait variation with key climatic drivers (e.g. temperature and precipitation) for individuals at sites that have been monitored multiple years
Delivery method:	Static datasets available for download

Product Description:

Variability in phenophase onset dates that corresponds to climatic variability at a site is a proxy for the degree to which species phenologies are sensitive, or responsive, to climatic drivers (Pau et al. 2011, Cook et al. 2012). These metrics correspond to the ability of a species to track climate change, and greater sensitivities to climate have been linked to increased species performance (e.g. population growth) in the context of ongoing climate change (Cleland et al. 2012). This product will calculate correlations between phenophase onset dates and climatic variables for individuals and sites for which there are at least 3 years of detectable phenophase onset data (i.e. first positive phenophase observation records made within 7 or 14 days of previous negative observation) records. Phenophases included in these calculations will include "Breaking leaf buds", "Initial growth", "Open flowers", and "Ripe fruit". Climatic datasets that will be explored for use in this analysis include monthly and daily weather parameters from the PRISM (http://www.prism.oregonstate.edu/) and Daymet (http://daymet.ornl.gov/) gridded datasets. We will calculate responsiveness of phenophase onset dates to individual climate variables known to be phenological drivers, (including minimum and maximum temperature and precipitation occurrence for relevant time periods depending on species and phenophase activity times). Responsiveness metrics will be measured in # days/°C or # of days/mm annual precipitation. Output will include site level variability amongst individuals. The resulting static dataset will be updated annually. A phenological responsiveness database will be useful in research to understand species vulnerability to climate change and variability, as well as allow researchers to investigate how species with varying evolutionary origins, growth forms, or habitat characteristics may differ in their response to climate. In addition, these measures of sensitivity will form the underlying relationships in multi-driver phenology models (see data product D3).

Product Identification Number:	C2
Product Suite:	Species responsiveness
Product Name:	Integrated species responsiveness
Subproduct Name(s):	NEON domain responsiveness, Protected area responsiveness, Ecoregion responsiveness, Pheno-region responsiveness
Ecological Scale:	Species
Spatial Scale:	Region
Short Description:	Integration of responsiveness estimates across sites to generate species level metrics of phenological plasticity
Delivery method:	Static datasets available for download

Product Description:

This product builds upon site-level species responsiveness by generating a dataset that utilizes geographic and climatic variability within species distributions to calculate species-level metrics of phenological variability at the regional level. Species responsiveness values are provided for regions that have been determined to be of distinct ecological and climatic interest to the data user community. These will include the regions delineated by protected areas (e.g., National Parks and National Wildlife Refuges), Ecoregions (e.g. Bailey's ecoregions, Bailey et al. 1994), NEON domains (http://www.neoninc.org/), and pheno-regions (e.g. Buitenwerf et al. 2015). Estimation of species level responsiveness will use the same climate driver variables and phenophases as used in the site-based calculations. Responsiveness metrics will be measured in # days/°C or # of days/mm annual precipitation (or other relevant climatic drivers). Output will include species level variability amongst sites. The resulting static datasets (by region) will be available for download and will be updated annually. In addition to the site level responsiveness datasets (C1), these regional datasets can be used to develop multi-driver phenology models (see data product D3).

Product Identification Number:	D1
Product Suite:	Phenology models
Product Name(s):	Extended Spring indices (SI-x; leaf and bloom)
Subproduct Name(s):	Protected area Spring Indices
Ecological Scale:	Species
Spatial Scale:	Continent
Short Description:	Species-specific mathematical models that predict first leaf and bloom dates based on climatic drivers.
Delivery method:	Source data and code will be available for download for each developed model in a USA-NPN managed database

Product Description:

The Extended Spring Indices (SI-x) are models that scientists have developed to predict the "start of spring" at a particular location. Using historical observations of the timing of first leaf and first bloom in cloned lilacs and honeysuckles, as well as daily observations from nearby weather stations, scientists have been able to determine the weather conditions that precede general spring leaf-out for a wide range of plants. Like many other deciduous plants in temperate systems, these plants put on their leaves as temperatures warm in late winter and early spring. Recent work extended the original Spring Indices (SI-o; Schwartz 1997) from high latitude regions to subtropical environments by removing a chilling requirement (Schwartz et al 2013, Ault et al 2015).

Using the Extended Spring Index models, scientists can look at how much the start of spring has varied from one year to the next at a particular location, and whether recent years are dramatically different from the past or not. The models can also be used to forecast when selected plants might bloom or put on leaves in future years.

Product Identification Number:	D2
Product Suite:	Phenology models
Product Name(s):	Ornamental shrub algorithms
Subproduct Name(s):	First Leaf and First Bloom for (a) Lilac, (b) Arnold Red Honeysuckle, and (c) Zabelii Honeysuckle
Ecological Scale:	Species
Spatial Scale:	Continent
Short Description:	Species-specific mathematical models that predict phenometrics based on climatic drivers
Delivery method:	Source data and code will be available for download for each developed model in a USA-NPN managed database

Product Description:

The Extended Spring Indices (Product D1) is created by combining three species specific models for (a) Lilac, (b) Arnold Red Honeysuckle, and (c) Zabelii Honeysuckle. The Extended Spring Indices (SI-x) are models that scientists have developed to predict the "start of spring" at a particular location. Using historical observations of the timing of first leaf and first bloom in cloned lilacs and honeysuckles, as well as daily observations from

nearby weather stations, scientists have been able to determine the weather conditions that precede general spring leaf-out for a wide range of plants. Like many other deciduous plants in temperate systems, these plants put on their leaves as temperatures warm in late winter and early spring. Recent work extended the original Spring Indices (SI-o; Schwartz 1997) from high latitude regions to subtropical environments by removing a chilling requirement (Schwartz et al 2013, Ault et al 2015).

Product Identification Number:	D3
Product Suite:	Phenology models
Product Name(s):	Individual native taxa phenophase algorithms
Subproduct Name(s):	
Ecological Scale:	Species to functional group
Spatial Scale:	Region to Continent
Short Description:	Species-specific mathematical models that predict phenometrics based on climatic drivers for select taxa.
Delivery method:	Source data and code will be available for download for each developed model in a USA-NPN managed database

Product Description:

Phenology models can be used at the national level to understand climate change impacts, spatiotemperal variation in phenological activity, past phenological patterns, and to forecast future short- and long-term impacts. These models predict phenometrics based on mathematical relationships between climatological drivers and phenological activity. To construct models for a suite of species of interest, we will establish threshold phenological models, or algorithms, that predict day of year (DOY) of the threshold phenometric event, (e.g., onset, end or peak), using established relationships between climate and phenology. These models will be based on integrated metrics of responsiveness to climate, including those generated in the species responsiveness database (products C1 and C2). To determine the optimum model to predict DOY (P) for each species (i) and phenophase (j) of interest, we will explore the use of Growing Degree Day (GDD) models (Kimball et al. 2014), modified Si-X models (Schwartz et al. 2013, Ault et al., 2015), and multi-driver models (e.g. temperature and precipitation, vapor pressure deficit) (Jolly et al. 2005, Diez et al. 2014). Later iterations will include location (k) and time (l). Generic phenoclimatic models responses thus can be described as P_{ijkl}. Models will be tested and refined until sufficient certainty is established in conjunction with continued data collection.

Models will first be implemented for specific species or regions of interest to provide key stakeholders (e.g. US protected areas) with estimates of ongoing and predicted phenological change, and with graphical resources to aid in climate change adaptation planning and communication with the public on climate change impacts.

Product Identification Number:	D4
Product Suite:	Phenology models
Product Name:	Data-model fusion
Ecological Scale:	Species to functional group
Spatial Scale:	Region to Continent
Short Description:	Dynamic models couple existing phenology static models with incoming status and phenometrics *in-situ* data
Delivery method:	TBD

Product Description:

Climate data streams and phenology data streams will be automatically and dynamically combined and synthesized to improve phenology model algorithms based on real-time incoming observational data. Initial steps will include combining models with historical data and building a near real-time data processing framework. This approach allows us to test models and identify areas where more information is needed to improve their performance, and also dynamically improve short-term forecasts based on current meteorology (and ultimately longer-term forecasts based on ongoing changes to patterns of atmospheric circulation, see E5). Uncertainty analysis is a central feature of these models; allowing for model improvements based on known gaps in understanding of drivers or data availability will greatly improve the predictive functionality of these models (Keenan et al. 2011).

Product Identification Number:	E1
Product Suite:	Gridded phenology maps
Product Name:	Gridded historical maps (1981 - near real-time)
Format:	The data are stored in a PostGIS database and made available via WCS and WMS. Maps are 2.5-4 km resolution.
Ecological Scale:	Species to functional group
Spatial Scale:	Continent
Short Description:	Retrospective phenology modeling using historical gridded climatological data and meteorological data
Delivery method:	Visualize gridded maps on dynamic phenology data visualization tool; source data and code available for download as raster files from Geoserver.
Quality Checks:	Quality control and uncertainty estimation for gridded products in forthcoming USGS Open File Report
Data Processing & Scientific Workflows:	Data processing and workflow in forthcoming USGS Open File Report. Technical documentation for accessing products and workflow/code documentation.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~150 GB
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
Repository for Data:	Data stored at USA-NPN. Metadata for these data is stored in the USGS Science Data Catalog, Ecosystems.data.gov and Data.gov, and ScienceBase.
Citation:	USA National Phenology Network. Year of dataset access. Name of data product, USA-NPN, Tucson, Arizona, USA. Data set accessed YYYY-MM-DD at http://dx.doi.org/10.5066/F7XD0ZRK
Digital Object Identifier (DOI)/Link:	SI-x Suite: http://dx.doi.org/10.5066/F7XD0ZRK
Product Description: Running models on historical independent datasets allow for detecting long-term patterns when there is a lack of available long term observational data by utilizing the predictive capacity of the algorithms describing the relationships between climate and phenology. These gridded maps are constructed by integrating phenology models with gridded historical climate datasets (e.g., NCEP (http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html) and PRISM (http://www.prism.oregonstate.edu/)).	

Product Identification Number:	E2
Product Suite:	Gridded phenology maps
Product Name:	Gridded 30 year average maps (1981-2010)
Subproduct(s) Name:	Extended SI-x 30 year average
Format:	These data are stored in a PostGIS database and made available via WCS and WMS. Maps are 2.5-4 km resolution.
Ecological Scale:	Species to functional group
Spatial Scale:	Continent
Short Description:	Average historical gridded climatological data
Delivery method:	Visualize gridded maps on dynamic phenology data visualization tool; source data and code available for download as raster files from Geoserver.
Quality Checks:	Quality control and uncertainty estimation for gridded products in forthcoming USGS Open File Report.
Data Processing & Scientific Workflows:	Data processing and workflow in forthcoming USGS Open File Report. Technical documentation for accessing products and workflow/code documentation.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~150 GB
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
Repository for Data:	Metadata for these data is or will be stored in the USGS Science Data Catalog, Ecosystems.data.gov and Data.gov, ScienceBase, Dryad and KNB.
Citation:	USA National Phenology Network. Year of dataset access. Name of data product, USA-NPN, Tucson, Arizona, USA. Data set accessed YYYY-MM-DD at http://dx.doi.org/10.5066/F7XD0ZRK
Digital Object Identifier (DOI)/Link:	SI-x Suite: http://dx.doi.org/10.5066/F7XD0ZRK

Product Description:

These two layers show the 30-year average day of year for the First Leaf or First Bloom Indices. These layers are not available for individual species threshold models, only for the Spring Indices (the average of the three species).

These long-term averages were created by averaging the annual Spring Index layers generated for each year in the span 1981 - 2010, as described above for Historical Annual Spring Indices**,** where each year's grid depicts the day of year the Index requirements were reached in that year. These long-term average grids are calculated as follows:

((SI-x grid 1981) + SI-x grid 1982) + … + (SI-x grid 2010)) / 30

These annual grids were generated using historical PRISM data which were resampled using bilinear interpolation from the native 4km resolution to 2.5km resolution to match the resolution of the other gridded products in this suite. These layers will be re-calculated each decade, incorporating the previous decade's data, e.g. the layers will be recalculated in 2021 using data from 1991 - 2020.

Product Identification Number:	E3
Product Suite:	Gridded phenology maps
Product Name:	Gridded anomaly maps
Subproduct(s) Name:	Daily Spring Index Anomalies
Format:	The data are stored in a PostGIS database and made available via WCS and WMS. Maps are 2.5-4 km resolution.
Ecological Scale:	Species to functional group
Spatial Scale:	Continent
Short Description:	Comparison of contemporary modeling to 30 year average
Delivery method:	Visualize gridded maps on dynamic phenology data visualization tool; source data and code available for download as raster files from Geoserver.
Quality Checks:	Quality control and uncertainty estimation for gridded products in forthcoming USGS Open File Report.
Data Processing & Scientific Workflows:	Data processing and workflow in forthcoming USGS Open File Report. Technical documentation for accessing products and workflow/code documentation.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~150 GB
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
Repository for Data:	Data stored at USA-NPN. Metadata for these data is stored in the USGS Science Data Catalog, Ecosystems.data.gov and Data.gov, and ScienceBase.
Citation:	USA National Phenology Network. Year of dataset access. Name of data product, USA-NPN, Tucson, Arizona, USA. Data set accessed YYYY-MM-DD at http://dx.doi.org/10.5066/F7XD0ZRK
Digital Object Identifier (DOI)/Link:	SI-x Suite: http://dx.doi.org/10.5066/F7XD0ZRK

Product Description:

These layers show the difference, in days, between the Daily Contemporary and Short-term Forecasted Spring Indices and the 30-Year Average for Spring Indices. The layers show how advanced or lagged the day of year of the First Leaf and First Bloom Indices are, for the current year in a given location, compared to long-term averages. These value are

calculated as follows:

(Current Day's Values - 30-Year Average Values)

such that negative values represent locations that have reached or are anticipated to reach the SI-x requirements earlier than average, and positive values represent locations that have reached or are anticipated to reach the SI-x requirements later than average.
There is a layer for each day of the year, including the present day and up through six days into the future based on NDFD forecast data. These layers are re-generated following the same schedule as the Daily Contemporary Data, incorporating improvements to the data as described above in the Contemporary Data section.

These layers are not available for individual species threshold models, only the Spring Indices (the average of the three species threshold models).

Product Identification Number:	E4
Product Suite:	Gridded phenology maps
Product Name:	Gridded daily model output (current year, up to current day and 1-6 day forecast maps)
Subproduct(s) Name:	Current day maps of Spring Index First Leaf and First Bloom Daily Contemporary and Short-term Forecasted Spring Indices
Format:	The data are stored in a PostGIS database and made available via WCS and WMS. Maps are 2.5-4 km resolution.
Ecological Scale:	Species to functional group
Spatial Scale:	Continent
Short Description:	Phenology models are gridded using current weather data
Delivery method:	Visualize gridded maps on dynamic phenology data visualization tool; source data and code available for download as raster files from Geoserver.
Quality Checks:	Quality control and uncertainty estimation for gridded products in forthcoming USGS Open File Report.
Data Processing & Scientific Workflows:	Data processing and workflow in forthcoming USGS Open File Report. Technical documentation for accessing products and workflow/code documentation.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~150 GB
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
Repository for Data:	Data stored at USA-NPN. Metadata for these data is stored in the USGS Science Data Catalog, Ecosystems.data.gov and Data.gov, and ScienceBase.

Citation:	USA National Phenology Network. Year of dataset access. Name of data product, USA-NPN, Tucson, Arizona, USA. Data set accessed YYYY-MM-DD at http://dx.doi.org/10.5066/F7XD0ZRK
Digital Object Identifier (DOI)/Link:	SI-x Suite: http://dx.doi.org/10.5066/F7XD0ZRK

Product Description:

These layers represent the progression of the leaf and bloom Spring Indices in the current year. There is one layer for each day of the year up through the current day, plus six days into future. These grids are updated on a nightly process. A cell is not shaded with the day of year that the Spring Index requirements are met until the requirements for each of the three species threshold models have been met.

By adjusting the day of year that is viewed, the user can explore the locations where the Spring Index requirements have been reached, as well as pixels where the Spring Index requirements are anticipated to be met in the coming six days, based on short-term temperature forecast products (NDFD).

Each night, the layers are re-generated for the previous two days, the current day, and the next six days. This allows more stable data and better forecasts to be incorporated into each day's representation of the model. Because the short-term forecasts are adjusted daily, the pixels anticipated to reach the requirements for the Indices may vary from one day to the next.

Short term forecasts will use NCEP forecast data to provide predicted phenological activity up to 6 days in advance.

Product Identification Number:	E5
Product Suite:	Gridded phenology maps
Product Name:	Gridded projection maps (2017-2100)
Subproduct(s) Name:	N/A
Ecological Scale:	Species to functional group
Spatial Scale:	Continent
Short Description:	Phenology models are gridded using future weather and climate change scenarios to forecast phenometrics. Includes long-, and medium-term forecasts.
Delivery method:	Visualize gridded maps on dynamic phenology data visualization tool; source data and code available for download as raster files from Geoserver.

Product Description:

Phenology models are extended into the future using future weather and climate change scenarios to forecast phenological onset. Long-term projections are extended to 2100 in 30 year increments using published gridded climate change projections (e.g. CMIP5, http://cmip-pcmdi.llnl.gov/cmip5/ or CESM, http://www2.cesm.ucar.edu/). Spatially and temporally explicit forecast maps are creating by integrating models with gridded climate projection data.

Medium term forecasts (30-60 days) will be based on incoming large-scale atmospheric circulation data, e.g., the DYNAMO (Dynamics of the Madden Julian Oscillation) observation campaign based on sounding arrays and focused on the initiation phase of the MJO in the central Indian Ocean. The MJO is a low-latitude intra-seasonal oscillation that passes through a cycle of 60-90 days and is critical to short and long-range predictability of tropical and subtropical weather (Our Changing Planet Report, 2014). Medium-term forecasts will be used to communicate with stakeholders what phenological patterns to expect in the coming months, and to validate or adjust existing models.

Product Identification Number:	E6
Product Suite:	Gridded phenology maps
Product Name:	Gridded LSP maps
Subproduct Name:	Start of Season (SOS); End of Fall (EOF); Growing Season length summarized for protected areas
Ecological Scale:	Functional group
Spatial Scale:	Continent
Short Description:	LSP metrics for the day of year corresponding to the start of spring (SOS) and end of fall (EOF), as well as the growing season length based on the SOS and EOF.
Delivery method:	USA-NPN Geoserver and Visualization Tool

Product Description:

Land surface phenology (LSP) derived products generated by Josh Gray and colleagues will be delivered via the USA-NPN visualization tool and summarized for protected areas; this work is funded by NASA as an indicator of climate change impacts on land surface phenology (LSP-CI) (funding period 2016-2019). LSP-CI products will be delivered via the USA-NPN phenology visualization tool and the Geoserver Instance. These products aim to quantify within and across-season changes in the growing season of national ecosystems at multiple spatial scales and will include:

- LSP metrics for the day of year corresponding to the start of spring (SOS) and end of fall (EOF), as well as the growing season length based on the SOS and EOF.
- Long term normals (means) in SOS, EOF, and GSL, along with associated standard deviations and coefficients of variation to characterize the magnitude of inter-annual variation in each of these metrics.
- Long term trends in SOS, EOF, and GSL, along with measures of statistical significance for those trends.

The LSP-CI will be produced annually at 4 distinct scales of geographic aggregation: (1) as national-scale maps at 500-m spatial resolution using a widely used cartographic projection (e.g., Mercator-variant) and provided in file formats that are easily readable by common GIS software packages (e.g., GeoTIFFs); (2) as geographically aggregated values for each state and for each of the 8 NCA regions that are dominated by terrestrial ecosystems (i.e., excluding oceans and coasts); (3) as geographically aggregated values at the national scale; and (4) for each of 289 National Parks, Monuments, and Historical Sites. Annual values at each geographic scale will be provided from 2001 to present, and will be generated each year as new data become available.

Product Identification Number:	F1
Product Suite:	Gridded climate maps
Product Name:	Gridded 30 year average maps (1981-2010)
Subproduct(s) Name:	Daily 30-Year Average Temperature Accumulations
Format:	The data are stored in a PostGIS database and made available via WCS and WMS. Maps are 2.5-4 km resolution.
Ecological Scale:	N/A
Spatial Scale:	Continent
Short Description:	Average historical gridded AGDD data
Delivery method:	Visualize gridded maps on dynamic phenology data visualization tool; source data and code available for download as raster files from Geoserver.
Quality Checks:	Quality control and uncertainty estimation for gridded products in forthcoming USGS Open File Report.
Data Processing & Scientific Workflows:	Data processing and workflow in forthcoming USGS Open File Report. Technical documentation for accessing products and workflow/code documentation.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~150 GB
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
Repository for Data:	Data stored at USA-NPN. Metadata for these data is stored in the USGS Science Data Catalog, Ecosystems.data.gov and Data.gov, and ScienceBase.
Citation:	USA National Phenology Network. Year of dataset access. Name of data product, USA-NPN, Tucson, Arizona, USA. Data set accessed YYYY-MM-DD at http://dx.doi.org/10.5066/F7SN0723
Digital Object Identifier (DOI)/Link:	AGDD Suite: http://dx.doi.org/10.5066/F7SN0723

Product Description:

These layers show the average number of AGDD for every day of year; there is one layer available for each day of year, for each base temperature. These long-term averages were created by averaging the accumulated growing degree day grids for the same day of year over the span 1981 - 2010 for each base temperature. These averaged grids are calculated as follows:

((AGDD grid DOY 1, 1981) + (AGDD grid DOY 1, 1982) + … + (AGDD grid DOY 1, 2010)) / 30

These annual grids were generated using historical PRISM data which were resampled using bilinear interpolation from the native 4km resolution to 2.5km resolution to match the resolution of the other gridded products in this suite. These layers will be re-calculated

each decade, incorporating the previous decade's data, e.g. the layers will be recalculated in 2021 using data from 1991 - 2020. These grids are summed on day of year, as such, in leap years, December 31st is excluded.

Product Identification Number:	F2
Product Suite:	Gridded climate maps
Product Name:	Gridded anomaly maps
Subproduct(s) Name:	Daily AGDD Anomalies
Format:	The data are stored in a PostGIS database and made available via WCS and WMS. Maps are 2.5-4 km resolution.
Ecological Scale:	N/A
Spatial Scale:	Continent
Short Description:	Comparison of current daily AGDD to 30 year average
Delivery method:	Visualize gridded maps on dynamic phenology data visualization tool; source data and code available for download as raster files from Geoserver.
Quality Checks:	Quality control and uncertainty estimation for gridded products in forthcoming USGS Open File Report.
Data Processing & Scientific Workflows:	Data processing and workflow in forthcoming USGS Open File Report. Technical documentation for accessing products and workflow/code documentation.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~150 GB
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
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Digital Object Identifier (DOI)/Link:	AGDD Suite: http://dx.doi.org/10.5066/F7SN0723

Product Description:

These layers show the difference between the Daily Contemporary and Forecasted Temperature Accumulations and the 30-Year Average Temperature Accumulations, showing how much warmer or cooler the cumulative temperature is compared to long-term average cumulative temperature conditions, on any day of year. These values are calculated as follows:

(Current Day's Values - 30-Year Average Values)

such that negative values represent locations that have not yet reached the average heat accumulation this year for that day and positive values represent locations that have exceeded the average number of heat units accumulated this year for that day. There is a layer for each day of the year, including the current day and one through six days into the future based on the NDFD forecast layers.

Product Identification Number:	F3
Product Suite:	Gridded climate maps
Product Name:	Daily Contemporary and Forecasted Temperature Accumulations
Subproduct(s) Name:	Current daily maps of AGDD, base temp 32°F; base temp 50°F; Current daily maps of Tmin; current daily maps of Tmax
Format:	The data are stored in a PostGIS database and made available via WCS and WMS. Maps are 2.5-4 km resolution.
Ecological Scale:	N/A
Spatial Scale:	Continent
Short Description:	AGDD models are gridded using current and short-term forecasted weather data
Delivery method:	Visualize gridded maps on dynamic phenology data visualization tool; source data and code available for download as raster files from Geoserver.
Quality Checks:	Quality control and uncertainty estimation for gridded products in forthcoming USGS Open File Report.
Data Processing & Scientific Workflows:	Data processing and workflow in forthcoming USGS Open File Report. Technical documentation for accessing products and workflow/code documentation.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~150 GB
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
Repository for Data:	Data stored at USA-NPN. Metadata for these data is stored in the USGS Science Data Catalog, Ecosystems.data.gov and Data.gov, and ScienceBase.
Citation:	USA National Phenology Network. Year of dataset access. Name of data product, USA-NPN, Tucson, Arizona, USA. Data set accessed YYYY-MM-DD at http://dx.doi.org/10.5066/F7SN0723
Digital Object Identifier (DOI)/Link:	AGDD Suite: http://dx.doi.org/10.5066/F7SN0723
Product Description:	

These layers represent the amount of heat accumulated in each pixel. There is one layer for each day of the year up through the current day, plus six days into the future. Grid cell values begin at 0, and increase as heat units begin to accumulate. These grids are updated on a nightly process.

By adjusting the day of year that is viewed, the user can explore the amount of heat accumulated at any location on that day. The user may also explore the growing degree days anticipated to accumulate in the next one to six days, based on short-term temperature forecast products (NDFD).

Each night, the layers are re-generated for the previous two days, the current day, and the next six days. This allows more stable data and better forecasts to be incorporated into each day's representation of the model. Because the short-term forecasts are adjusted daily, pixels values may vary from one day to the next.

Product Identification Number:	F4
Product Suite:	Gridded climate maps
Product Name:	Gridded AGDD projection maps (2017-2100)
Subproduct(s) Name:	N/A
Ecological Scale:	Species to functional group
Spatial Scale:	Continent
Short Description:	AGDD models are gridded using future weather and climate change scenarios to forecast temperature accumulation. Includes long-, and medium-term forecasts.
Delivery method:	Visualize gridded maps on dynamic phenology data visualization tool; source data and code available for download as raster files from Geoserver.

Product Description:

AGDD models are extended into the future using future weather and climate change scenarios to forecast phenological onset. Long-term projections are extended to 2100 in 30 year increments using published gridded climate change projections (e.g. CMIP5, http://cmip-pcmdi.llnl.gov/cmip5/ or CESM, http://www2.cesm.ucar.edu/). Spatially and temporally explicit forecast maps are creating by integrating models with gridded climate projection data.
Medium term forecasts (30-60 days) will be based on incoming large-scale atmospheric circulation data, e.g., the DYNAMO (Dynamics of the Madden Julian Oscillation) observation campaign based on sounding arrays and focused on the initiation phase of the MJO in the central Indian Ocean. The MJO is a low-latitude intra-seasonal oscillation that passes through a cycle of 60-90 days and is critical to short and long-range predictability of tropical and subtropical weather (Our Changing Planet Report, 2014). Medium-term forecasts will be used to communicate with stakeholders what phenological patterns to expect in the coming months, and to validate or adjust existing models.

Product Identification Number:	F5
Product Suite:	Gridded climate maps
Product Name:	Known AGDD threshold to onset DOY conversion
Subproduct(s) Name:	N/A
Ecological Scale:	Species
Spatial Scale:	Region to continent
Short Description:	Allow data users to input known species threshold AGDD values to generate DOY values that represent phenophase onset DOY
Delivery method:	TBD
Product Description Customized graphs and maps of predicted phenometrics based on user-defined knowledge of specific species specific temperature thresholds.	

Product Identification Number:	F6
Product Suite:	Gridded climate maps
Product Name:	Interactive AGDD model generation
Subproduct(s) Name:	N/A
Ecological Scale:	Species
Spatial Scale:	Region to continent
Short Description:	Allow data users to manipulate start and end date for temp accumulation, set base temperature, and set known species-specific threshold to generate DOY values that represent phenophase onset DOY
Delivery method:	TBD
Product Description: Customized graphs and maps of predicted phenometrics based on user-defined knowledge of specific temperature thresholds, base temperatures, and timeframe in which temperature accumulation is critical.	

Product Identification Number:	G1
Product Suite:	Datastream integration
Product Name:	Climate-*in situ* integration
Ecological Scale:	Species
Spatial Scale:	Site
Short Description:	Daily and monthly climate data delivered alongside site-level phenometric data.
Delivery method:	Phenology Observation Portal (www.usanpn.org/results/data) USA-NPN API
Quality Checks:	
Data Processing & Scientific Workflows:	Daymet temperature (Tmin and Tmax) and precipitation data is summarized by site for the following seasons: Dec-Feb,Mar-May, Jun-Aug, Sept-Nov. Temperature data represent mean values, and precipitation data represent accumulated totals over the season.
Metadata:	
Volume Estimate:	
Backup & Storage:	
Repository for Data:	Daymet
Citation	Thornton, P.E., M.M. Thornton, B.W. Mayer, Y. Wei, R. Devarakonda, R.S. Vose, and R.B. Cook. 2016. Daymet: Daily Surface Weather Data on a 1-km Grid for North America, Version 3. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, USA. Date accessed: 2015/06/01-Present. Temporal range: 2008/01/01-present. Spatial range: N=52.00, S=14.53.DD, E=52.95, W=131.10. http://dx.doi.org/10.3334/ORNLDAAC/1328

Product Description:

Status and Intensity data, Individual phenometrics, and Site phenometric datasets are delivered with seasonal climate parameters using Daymet (http://daymet.ornl.gov/) datasets. Climate data are affiliated with sites and include seasonal summaries of maximum and minimum temperatures and precipitation. This integrated dataset will facilitate the production of the species responsiveness dataset and phenology models.

Product Identification Number:	G2
Product Suite:	Datastream integration
Product Name:	Phenocam-*in situ* integration
Ecological Scale:	Species to community to functional group
Spatial Scale:	Site
Short Description:	Delivery of integrated camera data and *in situ* observation data from NPDb
Delivery method:	TBD

Product Description:
Methods will be developed to estimate the agreement between phenocam and *in-situ* derived phenometrics for a range of species, sites and regions where phenocams are deployed along with the consistent collection of ground observations (e.g. USDA-ARS Jornada Experimental Range, New Mexico). Preliminary studies indicate variability in agreement between these methods depending on target phenophase and species (Dawn Browning, personal communication). Estimations of the levels of correspondence between these observation methods will allow for the improvement of phenological models and potentially allow for the integration of phenocam-derived phenometric data into the NPDb.

Product Identification Number:	G3
Product Suite:	Datastream integration
Product Name:	Satellite-*in situ* integration
Subproduct Name:	Start of Season (SOS); End of Fall (EOF); Growing Season length
Ecological Scale:	Community to Functional group
Spatial Scale:	Region to continent
Short Description:	Delivery of integrated land surface phenology data and *in situ* data
Delivery method:	TBD

Product Description:

Site phenometrics will be integrated with land surface phenology (LSP) derived products generated by Josh Gray and colleagues; this work is funded by NASA as an indicator of climate change impacts on land surface phenology (LSP-CI) (funding period 2016-2019). LSP-CI products will be delivered via the USA-NPN phenology visualization tool and the Geoserver Instance and allow data users to investigate the concordance of *in-situ* and LSP derived phenometrics. These products aim to quantify within and across-season changes in the growing season of national ecosystems at multiple spatial scales and will include:

• LSP metrics for the day of year corresponding to the start of spring (SOS) and end of fall (EOF), as well as the growing season length based on the SOS and EOF.
• Long term normals (means) in SOS, EOF, and GSL, along with associated standard deviations and coefficients of variation to characterize the magnitude of inter-annual

variation in each of these metrics.

• Long term trends in SOS, EOF, and GSL, along with measures of statistical significance for those trends.

The LSP-CI will be produced annually at 4 distinct scales of geographic aggregation: (1) as national-scale maps at 500-m spatial resolution using a widely used cartographic projection (e.g., Mercator-variant) and provided in file formats that are easily readable by common GIS software packages (e.g., GeoTIFFs); (2) as geographically aggregated values for each state and for each of the 8 NCA regions that are dominated by terrestrial ecosystems (i.e., excluding oceans and coasts); (3) as geographically aggregated values at the national scale; and (4) for each of 289 National Parks, Monuments, and Historical Sites. Annual values at each geographic scale will be provided from 2001 to present, and will be generated each year as new data become available.

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K. Gerst synthesized the content and drafted the report. A. Rosemartin, C. Enquist, E. Denny, T. Crimmins, L. Marsh, D. Moore and J. Weltzin contributed extensively to discussions regarding the nature of the proposed data product framework and the structure of the report, as well as provided meaningful edits. We appreciate the careful reviews of this report and/or discussion of the content provided by Sarah Elmendorf, Ben Ruddell, Rong Yu, Toby Ault, and Jessica Walker.

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