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USA National Phenology Network

USA National Phenology Network Data Product Catalog and Data Management Plan, v 3

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EXECUTIVE SUMMARY

The USA National Phenology Network (USA-NPN, www.usanpn.org) collects, organizes, and shares phenological data and information to aid decision-making, scientific discovery, and a broader understanding of phenology from a diversity of perspectives (USA-NPN 2019). The USA-NPN seeks to support decision-making in human health and natural resource management by freely providing salient and credible phenological data and information to a wide range of audiences. Here, we present our process for data product development and describe three suites of diverse and widely-used data products. This report also serves as our organizational Data Management Plan; in addition to the products, we detail the data sources, models and software used to create and deliver the products.

INTRODUCTION

Phenology, the timing of life cycle events such as leaf out, flowering, migration, and egg hatch, has clear value to a wide array of management decisions, ranging from when to treat invasive species to identifying which species are most sensitive to a changing climate. In addition, phenology is one of the most responsive metrics to changing environmental conditions (IPCC 2007, USGCRP 2018). In recent decades, widespread changes in phenology have been documented, with differential responses among species and cascading food web effects (Heberling et al. 2019). Such phenological shifts, with attendant impacts on species abundance and distribution, community composition and structure, and ecosystem functioning, are expected to continue (Thackeray et al. 2016).

The USA National Phenology Network (USA-NPN) is a national-scale monitoring and research initiative focused on collecting, organizing and delivering phenological data and information across the U.S. to support decision-making and to advance basic science. The data and information products offered by the USA-NPN help natural resource managers make better decisions related to seasonal plant, animal and habitat activity, and to better understand and manage biological invasions, vectors of disease, public health and safety, fish and wildlife populations for sustainable harvest, and recreation. For example, the 6-day Emerald Ash Borer Pheno Forecast enables managers to more effectively time treatment. USA-NPN data and products support academic research on invasive species, phenological mismatch, projections of seasonal change and enable the calibration of remotely-sensed phenology data. This report describes the USA-NPN's approach and future plans for data product development, including the curation of data throughout the life cycle. We detail our currently available products in a Catalog, and provide information on the inputs, models and software that comprise the data life cycle. This document contains all the required elements of a Data Management Plan, consistent with federal open data policy requirements.

DEVELOPMENT PROCESS

The USA-NPN engages stakeholders to guide the prioritization, selection, and development of data products and tools. Our approach is a coordinated effort to seek input from existing and new stakeholder audiences by cultivating relationships, building collaborative teams, and actively involving data users throughout the process of scoping and developing products to meet their needs (Figure 1). We have formalized our processes for stakeholder engagement following the tenets of knowledge co-production, recognizing that deeper engagement and collaboration with stakeholders to identify high priority products as well as modes of delivery will result in increased likelihood that the products will be used in making meaningful decisions. In addition, we document workflows and lessons learned as we deliver continental scale, high quality data in compliance with standards in the field.

Figure 1: USA-NPN framework for developing data products that meet stakeholder needs.

The USA-NPN is currently focusing on several topical areas of management concern where relevant and timely phenological information can improve short-term decision-making and long-term planning. These topical areas include insect pests, invasive plants, aeroallergenic plants, and migratory birds. We are also working with agency partners on the topic of future changes in spring arrival as a facet of climate adaptation.

Data Curation Through the Life Cycle

To fulfill partner needs and sustain a robust infrastructure, the USA-NPN develops data products with careful attention to data management practices throughout the data life cycle. Key points of contact are listed in product metadata and at www.usanpn.org/staff. All products are developed in compliance with federal open data policy, and are freely available with attribution (CC BY license; for further information see Rosemartin et al., 2018b). Figure 2 depicts the relationship of product suites to each other, and to the data sources (Inputs). Data products that are not yet reviewed and published are described on the USA-NPN New Products page and denoted as 'provisional'. USA-NPN data products, inputs (data sources), models and software/code are described in each of the following sections, following elements in the United States Geological Survey Data Life Cycle.

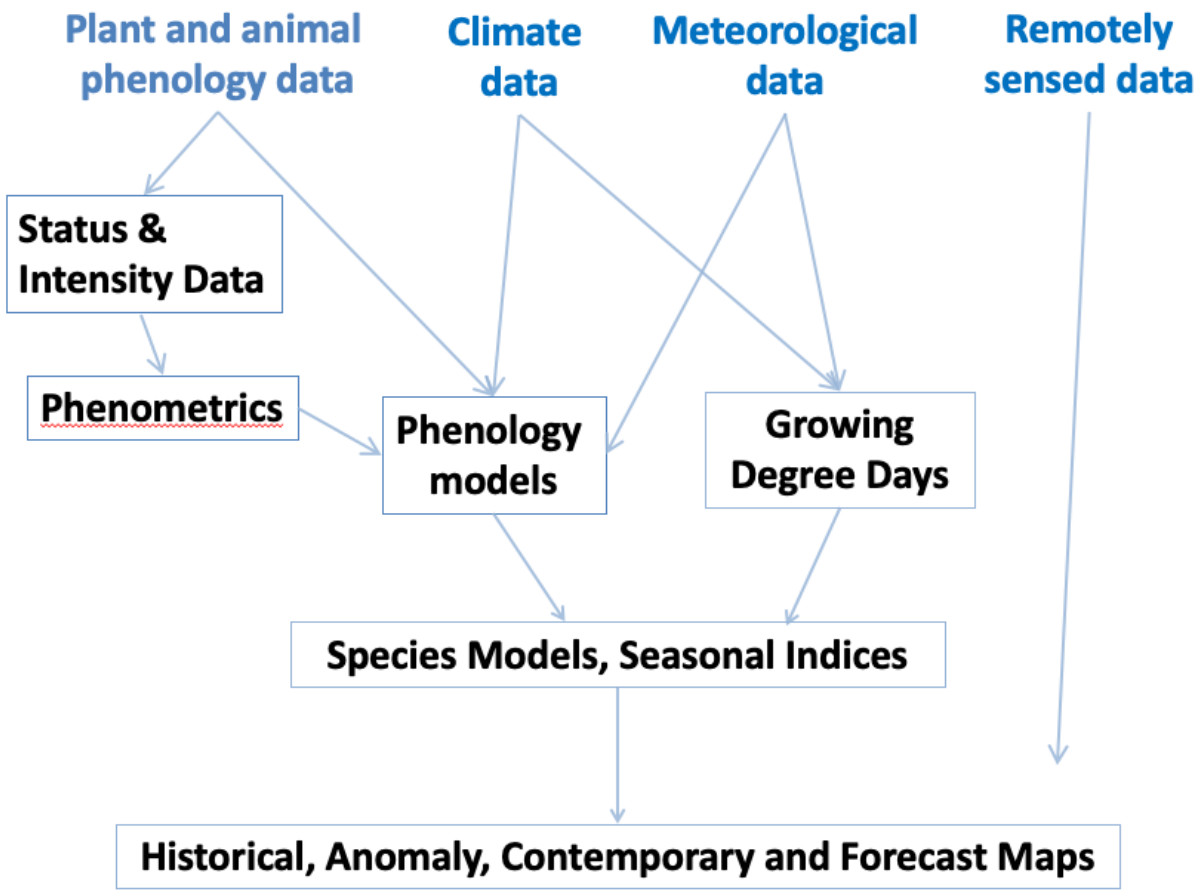

Figure 2: Relationships between data product suites demonstrating how each category provides a foundation for, or is used to derive, other suites of products. All **Products** delivered by the USA-NPN are represented in black text, and **Inputs** (data sources) are represented in blue text.

DATA PRODUCT CATALOG

Product number: **Product suite:** **Product name:**	**A1** Observational Data Phenophase Status and Intensity Data
Subproduct name(s):	N/A
Format:	Data are stored in MySQL database and available in CSV format and by web service as JSON or XML.
Ecological scale:	Individual organism (plants); Species at a site (animals)
Spatial scale:	Site
Short description:	Status records of presence or absence of the phenophase, as well as information about the degree to which the phenophase was expressed (intensity), for each individual plant or species of animal at a site for each site visit.

Delivery method(s):	Phenology Observation Portal rnpn R library USA-NPN API
Relevant citations:	Denny et al. (2014), Rosemartin et al. (2018a)
Input data:	Plant and Animal Phenology Data for the United States Lilac and Honeysuckle Data 1956-2008 NEON Phenology Data
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 are stored in ScienceBase (US Geological Survey, USGS), The Knowledge Network for Biocomplexity and ReDATA (University of Arizona, UA)
Citation:	USA National Phenology Network. Year of dataset access. Plant and Animal Phenology Data. Data type: Status and Intensity. [Date range of data used] for Region: [Coordinates]. USA-NPN, Tucson, Arizona, USA. Data set accessed [Date] at http://doi.org/10.5066/F78S4N1V
Digital Object Identifier (DOI)/Link:	http://dx.doi.org/10.5066/F78S4N1V

Product Description:
In situ phenology data for over 1000 species of plants and animals (2009-present) and data on lilacs and honeysuckles (1956-present), across the United States. The data consist of status records of presence or absence of the phenophase, as well as information about the degree to which the phenophase was expressed (intensity), for each individual plant or species of animal at a site for each site visit. These data were collected by volunteer observers, and are archived and distributed by the USA National Phenology Network (www.usanpn.org). Protocols are available in Denny et al. (2014) and further description is available in Rosemartin et al. (2018a).
Note that DAYMET Gridded Climate Variables are extracted based on site coordinates and delivered alongside this product to facilitate analysis, in the Phenology Observation Portal and the rnpn R library.
Datum is WGS84.

Product Number:	**A2**
Product Suite:	**Observational Data**
Product Name:	Individual Phenometrics
Subproduct(s):	Individual Phenometrics Individual Phenometrics with Intensity Metrics (*potential future data product*)
Format:	Data are stored in MySQL database and available in CSV format and by web service as JSON or XML.
Ecological Scale:	Individual organism (plants); Species at a site (animals)
Spatial Scale:	Site

Short Description:	Estimates of the dates of all onsets and ends of a phenophase for individual plants and for animal species at a site during a user-defined time period.
Delivery method(s):	Phenology Observation Portal rnpn R library USA-NPN API
Relevant Citations:	Rosemartin et al. (2018a) describes the dataset. Rosemartin et al. (2015) provides the lilac and honeysuckle data 1956-2013 with additional quality control.
Input data:	Plant and Animal Phenology Data for the United States Lilac and Honeysuckle Data 1956-2008 NEON Phenology Data
Quality Checks:	Data Quality Assurance and Quality Control Information Sheet
Data Processing & Scientific Workflows:	See metadata and Rosemartin et al. (2018a)
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 are stored in ScienceBase (USGS) and ReDATA (UA).
Citation:	USA National Phenology Network. Year of dataset access. Plant and Animal Phenology Data. Data type: Individual Phenometrics. [Date range of data used] for Region: [Coordinates]. USA-NPN, Tucson, Arizona, USA. Data set accessed [Date] at http://doi.org/10.5066/F78S4N1V
Digital Object Identifier (DOI)/Link:	http://dx.doi.org/10.5066/F78S4N1V

Product Description:
In situ phenology data for over 1000 species of plants and animals (2009-present) and data on lilacs and honeysuckles (1956-present), across the United States. The data consist of estimates of the dates of all onsets and ends of a phenophase for individual plants and for animal species at a site during a user-defined time period. These data were collected by volunteer observers, and are archived and distributed by the USA National Phenology Network (www.usanpn.org). Protocols are available in Denny et al. (2014) and further description is available in Rosemartin et al. (2018a) and Rosemartin et al. (2015).
Note that DAYMET Gridded Climate Variables are extracted based on site coordinates and delivered alongside this product to facilitate analysis, in the Phenology Observation Portal and the rnpn R library.
Datum is WGS84.

Product Number:	**A3**
Product Suite:	**Observational Data**
Product Name:	Site Phenometrics
Subproduct Name:	N/A

Format:	Data are stored in MySQL database and available in CSV format and by web service as JSON or XML.
Ecological Scale:	Species
Spatial Scale:	Site to region
Short Description:	Estimates of mean phenophase onset and end dates for species at a site during a user-defined time period.
Delivery method(s):	Phenology Observation Portal rnpn R library USA-NPN API
Relevant citations:	Rosemartin et al. (2018a)
Input data:	Plant and Animal Phenology Data for the United States Lilac and Honeysuckle Data 1956-2008 NEON Phenology Data
Quality Checks:	Data Quality Assurance and Quality Control Information Sheet
Data Processing & Scientific Workflows:	See metadata and Rosemartin et al. (2018a)
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 are stored in ScienceBase (USGS) and ReDATA (UA).
Citation:	USA National Phenology Network. Year of dataset access. Plant and Animal Phenology Data. Data type: Site Phenometrics. [Date range of data used] for Region: [Coordinates]. USA-NPN, Tucson, Arizona, USA. Data set accessed [Date] at http://doi.org/10.5066/F78S4N1V
Digital Object Identifier (DOI)/Link:	http://dx.doi.org/10.5066/F78S4N1V
Product Description: In situ phenology data for over 1000 species of plants and animals (2009-present) and data on lilacs and honeysuckles (1956-present), across the United States. The data consist of estimates of the dates of first onset and last end for a phenophase, averaged across individuals of the same species at a site, during a user-defined time period. These data were collected by volunteer observers, and are archived and distributed by the USA National Phenology Network (www.usanpn.org). Protocols are available in Denny et al. (2014) and further description is available in Rosemartin et al. (2018a). Note that DAYMET Gridded Climate Variables are extracted based on site coordinates and delivered alongside this product to facilitate analysis, in the Phenology Observation Portal and the rnpn R library. Datum is WGS84.	

Product Number: **Product Suite:** **Product Name:**	**A4** **Observational Data** Magnitude Phenometrics
Subproduct Name:	N/A
Format:	Data are stored in MySQL database and available in CSV format and by web service as JSON or XML.
Ecological Scale:	Species

Spatial Scale:	Site to region
Short Description:	A suite of eight metrics that describe the degree to which a phenophase is expressed across multiple individuals or sites, summarized for a given time interval.
Delivery method(s):	Phenology Observation Portal rnpn R library USA-NPN API
Relevant citations:	Rosemartin et al. (2018a)
Input data:	Plant and Animal Phenology Data for the United States Lilac and Honeysuckle Data 1956-2008 NEON Phenology Data
Quality Checks:	Data Quality Assurance and Quality Control Information Sheet
Data Processing & Scientific Workflows:	See metadata and Rosemartin et al. (2018a)
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 are stored in ScienceBase (USGS) and ReDATA (UA).
Citation:	USA National Phenology Network. Year of dataset access. Plant and Animal Phenology Data. Data type: Magnitude Phenometrics. [Date range of data used] for Region: [Coordinates]. USA-NPN, Tucson, Arizona, USA. Data set accessed [Date] at http://doi.org/10.5066/F78S4N1V
Digital Object Identifier (DOI)/Link:	http://dx.doi.org/10.5066/F78S4N1V
Product Description: In situ phenology data for over 1000 species of plants and animals (2009-present) and data on lilacs and honeysuckles (1956-present), across the United States. This product consists of a suite of eight metrics that describe the degree to which a phenophase is expressed across multiple individuals or sites, summarized for a given time interval. These data were collected by volunteer observers, and are archived and distributed by the USA National Phenology Network (www.usanpn.org). Protocols are available in Denny et al. (2014) and further description is available in Rosemartin et al. (2018a). Datum is WGS84.	

Product Number:	**B1**
Product Suite:	**Gridded Phenology Maps**
Product Name:	Spring Indices
Sub-product(s):	Reference Spreadsheet with all individual raster layers Spring Indices, Historical Annual (Rows 10-17) Spring Indices, Current Year (Rows 18-25 and 48-55) Spring Indices, Daily and Historical Annual Anomaly (Rows 26-27 and 64-65) Spring Indices, 30 Year Average (Rows 28-31) Historical Spring Indices, BEST (Rows 32-33)

	Historical Spring Indices, NCEP (Rows 34-43 and 56-63) Spring Indices, Return Interval (Rows 75, 76) Spring Indices, Projections (*potential future product*) ***To be Archived*** Spring Indices, 30 Year Average (*1981-2010 normals*) Spring Indices, Daily and Historical Annual Anomaly (*1981-2010 normals*) Spring Indices, Return Interval (*1981-2010 normals*)
Format:	The data are stored in a PostGIS database and made available via WCS and WMS via Geoserver. Maps are 2.5-4 km resolution.
Ecological Scale:	Species to functional group
Spatial Scale:	Continent
Short Description:	Rasters with the day of year values that model requirements for the Extended Spring Indices are met.
Delivery method(s):	Geoserver Request Builder Visualization Tool rnpn R library Archived data are available as GeoTIFFs via the University of Arizona's ReDATA
Input:	RTMA/URMA and PRISM data
Quality Checks:	See Crimmins et al. (2017)
Data Processing & Scientific Workflows:	See Crimmins et al. (2017) 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 (archived products are stored at UA's ReDATA). Metadata for these data are stored in ScienceBase (USGS) and ReDATA (UA).
Citation:	USA National Phenology Network. [Year Published] [Dataset Title] as of [DOY] for Region [Coordinates]. [Parameterized URL for Data Download]. USA-NPN, Tucson, Arizona, USA. Data set accessed YYYY-MM-DD at http://dx.doi.org/10.5066/F7XD0ZRK
Digital Object Identifier (DOI)/Link:	http://dx.doi.org/10.5066/F7XD0ZRK

Product Description:
A series of gridded products enabling researchers to analyze historical and contemporary data related to the Extended Spring Indices. The Extended Spring Indices are mathematical models that predict the "start of spring" (timing of leaf out or bloom for species active in early spring) at a particular location. These models were constructed using historical observations of the timing of first leaf and first bloom in a cloned lilac cultivar (*Syringa* x *chinensis* 'Red Rothomagensis') and two cloned honeysuckle cultivars (*Lonicera tatarica* 'Arnold Red' and *L. korolkowii* 'Zabelii'). Primary inputs to the model are temperature and weather events, beginning January 1 of each year (Ault et al., 2015). The model

output is the day of year that a particular location met the requirements of one of the Spring Index models (First Leaf or First Bloom).

Product Number: **Product Suite:** **Product Name:**	**B2** **Gridded Phenology Maps** Pheno Forecasts
Subproduct(s) Name:	Reference spreadsheet rows 78-91: Apple maggot (10.25422/azu.data.14272676.v1) Asian longhorned beetle (10.25422/azu.data.14272571.v1) Bagworm (10.25422/azu.data.14272697.v1) Bronze birch borer (10.25422/azu.data.14272385.v1) Buffelgrass (10.25422/azu.data.14273081.v1) Eastern tent caterpillar (10.25422/azu.data.14272610.v1) Emerald ash borer (10.25422/azu.data.14272427.v1) Gypsy moth (10.25422/azu.data.14272598.v1) Hemlock woolly adelgid (10.25422/azu.data.14272370.v1) Lilac borer (10.25422/azu.data.14272664.v1) Magnolia scale (10.25422/azu.data.14272619.v1) Pine needle scale (10.25422/azu.data.14272577.v1) Winter moth (10.25422/azu.data.14272625.v1) Winter wheat (10.25422/azu.data.14272703.v1)
Format:	The data are stored in a PostGIS database and made available via WCS and WMS via Geoserver. Maps are 2.5 resolution.
Ecological Scale:	Species
Spatial Scale:	Region to Continent
Short Description:	Pheno Forecast maps depict, on a given day, the status of a species' life cycle stage across the contiguous United States.
Delivery method(s):	Geoserver Request Builder Visualization Tool Swagger UI
Input:	RTMA/URMA data
Quality Checks:	Annual validation results available upon request; data are not quality checked beyond the measures applied to the underlying AGDD product.
Data Processing & Scientific Workflows:	Crimmins et al. 2020b, Crimmins et al. (in prep) and product metadata
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~50Gb
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 are stored in ScienceBase (USGS) and ReDATA (UA).
Citation:	USA National Phenology Network. [Year Published] [Dataset Title] as of [DOY] for Region [Coordinates]. [Parameterized URL for Data Download]. USA-NPN, Tucson, Arizona, USA. Data set accessed at [DOI].

Digital Object Identifier (DOI)/Link:	Listed above for each forecast.

Product Description

Pheno Forecast maps predict key life cycle stages in a range of species to improve conservation and management outcomes. For insect pest species, Pheno Forecasts are based on published growing degree day (GDD) thresholds for key points in species life cycles. For winter wheat, maps are based on growing degree days with photoperiod and chilling controls. For buffelgrass, maps are based on 24-day precipitation accumulations. These maps are updated daily and available 6 days in the future.

Product Number: **Product Suite:** **Product Name:**	**B3** **Gridded Phenology Maps** Gridded Land Surface Phenology Maps
Subproduct(s) Name:	Reference spreadsheet rows 66-74: Start of season metrics (mid greenup) End of season metrics (mid greendown) Growing season metrics (EVI area under the curve)
Format:	The data are stored in a PostGIS database and made available via WCS and WMS via Geoserver. Maps are 2.5-4 km resolution.
Ecological Scale:	Functional group
Spatial Scale:	Region to Continent
Short Description:	Land Surface Phenology products provide satellite-derived metrics related to start and end of the growing season.
Delivery method(s):	Geoserver Request Builder Visualization Tool
Input:	MODIS Land Surface Phenology Data
Quality Checks:	See metadata.
Data Processing & Scientific Workflows:	See metadata.
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	~200Mb
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 are stored in ScienceBase (USGS) and ReDATA (UA).
Citation:	USA National Phenology Network. [Year Published] [Dataset Title] as of [DOY] for Region [Coordinates]. [Parameterized URL for Data Download]. USA-NPN, Tucson, Arizona, USA. Data set accessed at 10.25422/azu.data.14270552.v1
Digital Object Identifier (DOI)/Link:	DOI: 10.25422/azu.data.14270552.v1

Product Description

This product is a synthesis of the MODIS Land Cover Dynamics dataset products to make them more accessible and usable by providing the most requested, value-added derivative layers: phenometric normals (average, median, std. dev., and median absolute deviation), trends (Theil-Sen slope magnitude and p-value), and interannual anomalies, as CONUS-wide mosaiced products in familiar, accessible file formats and projections.

Product Number: **Product Suite:** **Product Name:**	**C1** **Gridded Climate Maps** Accumulated Growing Degree Days
Subproduct(s) Name:	Reference spreadsheet Daily Temperature Accumulations, 30 Year Average (Rows 4-5) Daily Temperature Accumulations, Current Year (Rows 6-7 and 46-47) Daily Temperature Accumulations, Anomaly (Rows 8-9) Daily Temperature Minimums and Maximums (Rows 1-2 and 44-45) ***To be Archived*** Daily Temperature Accumulations, 30 Year Average (*1981-2010 normals*) Daily Temperature Accumulations, Anomaly (*1981-2010 normals*)
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:	Rasters with daily temperature accumulations, as well as long term averages and anomalies.
Delivery method(s):	Geoserver Request Builder Visualization Tool rnpn R library Archived data are available as GeoTIFFs via the University of Arizona's ReDATA
Input:	RTMA/URMA and PRISM data
Quality Checks:	See Crimmins et al. (2017)
Data Processing & Scientific Workflows:	See Crimmins et al. (2017) 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 (archived products are stored at UA's ReDATA). Metadata for these data are stored in ScienceBase (USGS) and ReDATA (UA).
Citation:	USA National Phenology Network. [Year Published] [Dataset Title] as of [DOY] for Region [Coordinates]. [Parameterized URL for Data Download]. USA-NPN, Tucson, Arizona, USA. Data set accessed at at http://dx.doi.org/10.5066/F7SN0723
Digital Object Identifier (DOI)/Link:	http://dx.doi.org/10.5066/F7SN0723
Product Description	

Rasters with daily temperature accumulations, as well as long term averages and anomalies. Products begin accumulation on January 1 each year and use either a 32F or 50F base temperature.

INPUTS, MODELS AND SOFTWARE BEHIND THE DATA PRODUCTS

Data Inputs – Existing Collections

1	Lilac and Honeysuckle Data 1956-2008
Description:	This dataset represents the legacy portion of the lilac and honeysuckle phenology data collected by the Western and Eastern Networks beginning in the 1950's. It was digitized and curated by Dr. Mark D. Schwartz at the University of Wisconsin until the founding of the USA-NPN in 2008.
Source:	Mark D. Schwartz (mds@uwm.edu)
Restrictions:	Unrestricted
Format:	CSV
Fees:	No fees apply
Quality Checks:	Data used as provided by source
Data Processing & Scientific Workflows:	Changes to data structure were made to conform to the National Phenology Database (CSV files split into tables for species, sites, and observational data reformatted from event to status data, to facilitate storage alongside contemporary status data).
Backup & Storage:	This data in its original format is not backed up or stored for the long term as a source.
Volume Estimate:	3 MB
Citation:	Schwartz, M.D. and J.M. Caprio, 2003, North American First Leaf and First Bloom Lilac Phenology Data, IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series # 2003-078. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

2	NEON Phenology Data
Description:	Quality-controlled, native sampling resolution data from in situ observations of plant leaf and flower phenophases at each of NEON's terrestrial sites (2013-present). Phenophase status and intensity definitions follow those of the USA National Phenology Network (USA-NPN). Status and intensity data are reported per phenophase per individual or patch, for each day observed. Data are collected by trained NEON technicians. For additional details, see the user guide, protocols, and science design listed in the Documentation section of this input's detailed webpage (link below).
Source:	National Ecological Observatory Network https://data.neonscience.org/data-products/DP1.10055.001
Restrictions:	None, released under a CC0 license
Format:	CSV
Fees:	No fees apply
Quality Checks:	NEON quality control checks are described on this page and documents linked therein https://data.neonscience.org/data-products/DP1.10055.001#collectionAndProcessing
Data Processing & Scientific Workflows:	NEON processing is described on this page and documents linked therein https://data.neonscience.org/data-products/DP1.10055.001#collectionAndProcessing
Backup & Storage:	Data are managed following NEON's processes https://www.neonscience.org/data-samples/data-management
Volume Estimate:	~550MB
Citation:	NEON (National Ecological Observatory Network). Plant phenology observations (DP1.10055.001). https://data.neonscience.org (accessed September 2, 2021)

3	PRISM Daily Temperature Values and Precipitation Totals
Description:	Gridded, daily temperature maximum and minimum and precipitation data across the continental U.S. at a 4km resolution.
Source:	PRISM Climate Group, Northwest Alliance for Computational Science & Engineering http://prism.oregonstate.edu
Restrictions:	Data may be freely reproduced and distributed for non-commercial purposes. When referring to the data, the source must be clearly and prominently stated and include, at a minimum, the name, URL, and the date of data creation. For example: PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 4 Feb 2004.
Format:	Zipped .BIL files
Fees:	No fees apply
Quality Checks:	Data used as provided by source
Data Processing & Scientific Workflows:	Scientific workflow described under Data Products that use this input.
Backup & Storage:	Data are catalogued in a PostGIS database hosted by the USA-NPN. The entirety of the server's file system is backed up weekly to Amazon Cloud Storage as a VM image. Source .BIL files are also maintained alongside PostGIS database for posterity.
Volume Estimate:	50GB
Citation:	PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, accessed, September 2015.

4	RTMA/URMA Real-Time, Hourly Temperature Values
Description:	Gridded, hourly temperature maximums and minimums across the continental U.S. at a 2.5km resolution, 2015-present, and 6-day forecasts, used to generate the gridded product suite.
Source:	NOAA, National Centers for Environmental Prediction (NCEP)
Restrictions:	Unrestricted
Format:	.BIN Files
Fees:	No fees apply
Quality Checks:	Data used as provided by source
Data Processing & Scientific Workflows:	Data are requested and cached on an as-needed basis.
Backup & Storage:	Data are catalogued in a PostGIS database hosted by the USA-NPN. The entirety of the server's file system is backed up weekly to Amazon Cloud Storage as a VM image.
Volume Estimate:	120GB
Citation:	De Pondeca, Manuel SFV, Geoffrey S. Manikin, Geoff DiMego, Stanley G. Benjamin, David F. Parrish, R. James Purser, Wan-Shu Wu et al. "The real-time mesoscale analysis at NOAA's national centers for environmental prediction: Current status and development." Weather and Forecasting 26, no. 5 (2011): 593-612. NOAA National Operational Model Archive & Distribution System, Unrestricted Meso-scale Analysis, accessed September 2015. Both datasets available at: http://www.nco.ncep.noaa.gov/pmb/products/rtma/

5	DAYMET Gridded Climate Variables
Description:	Gridded daily minimum and maximum temperatures, precipitation and daylength.
Source:	Oak Ridge National Laboratory, Distributed Active Archive Center http://daac.ornl.gov
Restrictions:	Unrestricted
Format:	TXT
Fees:	No fees apply
Quality Checks:	Data used as provided by source
Data Processing & Scientific Workflows:	Data is requested and cached on an as-needed basis. Incoming data are used to calculate a series of other aggregated values including: seasonal average minimum and maximum temperatures, seasonal average precipitation, daily accumulated precipitation, and daily, base 0C, accumulated growing degree days, represented in both Celsius and Fahrenheit.
Backup & Storage:	Data are catalogued in a MySQL database and hosted by the USA-NPN. The entirety of the server's file system is backed up weekly to Amazon Cloud Storage as a VM image.
Volume Estimate:	In raw text format, current data is ~ 2.5 GB, growing by ~ 500MB/year.
Citation:	Thornton, P.E., M.M. Thornton, B.W. Mayer, N. Wilhelmi, Y. Wei, R. Devarakonda, and R.B. Cook. 2014. Daymet: Daily Surface Weather Data on a 1-km Grid for North America, Version 2. Data set. 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/1219.

6	MODIS Collection 6 Land Surface Phenology Data
Description:	The MODIS Collection 6 Land Surface Phenology (MCD12Q2 V6) data product provides global land surface phenology metrics at 500 meters spatial resolution in yearly intervals from 2001 to 2017. The phenology metrics are derived from time series of MODIS-observed land surface greenness utilizing the 2-band Enhanced Vegetation Index (EVI2) calculated from MODIS Nadir BRDF-Adjusted Reflectance (NBAR).
Source:	MODIS/Terra and Aqua Land Cover Dynamics Yearly L3 Global 500 m SIN Grid V006 https://lpdaac.usgs.gov/products/mcd12q2v006/
Restrictions:	Unrestricted
Format:	TXT
Fees:	No fees apply
Quality Checks:	As described in User Guide.
Data Processing & Scientific Workflows:	Data is requested and cached on an as-needed basis to correspond with sites and years with observational data. Incoming data are used to calculate a series of derived phenometrics including greenness onset, peak, and end.
Backup & Storage:	Data are catalogued in a MySQL database and hosted by the USA-NPN. The entirety of the server's file system is backed up weekly to Amazon Cloud Storage as a VM image.
Volume Estimate:	In raw text format, current data is ~ 2.5 GB, growing by ~ 500MB/year.
Citation:	Friedl, M., Gray, J., Sulla-Menashe, D. (2019). *MCD12Q2 MODIS/Terra+Aqua Land Cover Dynamics Yearly L3 Global 500m SIN Grid V006* [Data set]. NASA EOSDIS Land Processes DAAC. Accessed 2019-10-04 from https://doi.org/10.5067/MODIS/MCD12Q2.006

Data Inputs – New Collections

1	Plant and Animal Phenology Data for the United States
Description:	Dataset currently consists of 24 million in situ phenology status records on over 1,000 species of plants and animals (as of April 2021). Data has been collected since 2009 by participants in *Nature's Notebook* across the United States, in accordance with our Terms of Use, since 2009. Data collection is ongoing. Updated summary statistics available at https://www.usanpn.org/data/dashboard and all data is available 48 hours after submission. A small number of these records are directly imported into the National Phenology Database from partner efforts, which use the exact USA-NPN protocols or very similar ones (e.g. New York Botanical Garden 2009-13: 42,130 records).
Exclusive Use:	No limitation on data use is made; Data Use Policy.
Restrictions:	Data are not restricted; Data Use Policy.

1	Plant and Animal Phenology Data for the United States
Format:	Data are stored in a MySQL database.
Protocols:	Standardized protocols were developed, vetted and documented in Denny et al. (2014).
Quality Checks:	Substantial quality assurance and quality control measures are in place, and documented in Appendix 2 of Rosemartin et al. (2018a).
Data Processing & Scientific Workflows:	N/A
Metadata:	FGDC metadata available at https://github.com/usa-npn/metadata
Volume Estimate:	In text format, the entirety of the raw, underlying data is ~9GB in size (as of September, 2021) increasing by ~25% annually.
Backup & Storage:	Server VM images are backed up weekly to Amazon Cloud Storage.
Repository for Data:	Operational, program and observational data are backed up twice monthly to ScienceBase for program recovery (not research) purposes.
Citation:	N/A
Digital Object Identifier (DOI)/Link:	N/A
Lifespan of Data	50+ years

Models

1	Extended Spring Indices
Description	The Extended Spring Indices are models that predict the "start of spring" (timing of leaf out or bloom in lilacs and honeysuckles) at a particular location, based on antecedent weather conditions (Schwartz, 1997, Schwartz et al., 2006, Schwartz et al., 2013, Ault et al., 2015).
Model Version	SI-x, Extended Spring Indices
Source/Link:	The model is described and implemented in Ault et al. (2015, Matlab) and Allstadt et al. (2015. C#). The USA-NPN version includes the Allstadt correction and is written in Python (https://github.com/usa-npn/gridded_models)
Model Input(s)	The model is calculated from daily minimum and maximum temperatures, which are used to generate growing degree hours and number of high energy synoptic events.
Model Output(s)	Estimated date of leaf out and bloom, an average of cloned and common lilacs and two species of honeysuckles.

1	Extended Spring Indices
Calibration Details	Calibration and validation approaches (comparisons to climate modes, and native species and crops) are described in the literature cited in the description above.

2	Accumulated Growing Degree Day and Precipitation Threshold Models
Description	Many species have established and published models to predict key life cycle stages. We leverage these models, particularly growing degree and precipitation threshold models, to predict life cycle stages across a range of species, in the suite of Pheno Forecast products.
Model Version	• Apple maggot, Adult emergence, 900 GDD, simple averaging (Wise et al. 2010), 1 Jan., 10°C (50°F) • Asian longhorned beetle, Adult emergence, 689.75 GDD, double sine (Kappel et al. 2017; R. Talbot Trotter, pers. comm.), 1 Jan., 10°C (50°F) • Bagworm, Caterpillar emergence , 600 GDD, simple averaging (Cornell Cooperative Extension 2010), 1 Mar., 0°C (32°F) • Bronze birch borer, Adult emergence, 450 GDD, double sine (Herms et al. 2004), 1 Jan., 10°C (50°F) • Buffelgrass, 50% greenness may occur in 1-2 weeks, 1-1.7 inches accumulated Precipitation over 24-day rolling timeframe (Wallace et al. 2016) • Buffelgrass (*Pennisetum ciliare* Linnaeus), 50% greenness will likely occur in 1-2 weeks, > 1.7 inches accumulated Precipitation over 24-day rolling timeframe (Wallace et al. 2016) • Eastern tent caterpillar , Caterpillar emergence , 90–190 GDD, simple averaging (Cornell Cooperative Extension 2010), 1 Mar., 10°C (50°F) • Emerald ash borer, Adult emergence, 450 GDD, double sine (Herms et al. 2019), 1 Jan., 10°C (50°F) • Gypsy moth, Caterpillar emergence, 571 GDD, double sine (Russo et al. 1993), 1 Jan., 3°C (37.5°F) • Hemlock woolly adelgid, Presence of eggs, 25 GDD, simple averaging (Mark Whitmore and Samita Limbu, pers. comm.), 1 Jan., 0°C (32°F) • Hemlock woolly adelgid, Presence of active nymphs, 1,000 GDD, simple averaging (Mark Whitmore and Samita Limbu, pers. comm.), 1 Jan., 0°C (32°F) • Lilac borer, Adult emergence, 330 GDD, double sine (Herms 2004), 1 Jan., 10°C (50°F) • Magnolia scale, Crawler emergence, 1938 GDD, double sine (Herms 2004), 1 Jan., 10°C (50°F) • Pine needle scale, Crawler emergence , 298–448 GDD, simple averaging (Cornell Cooperative Extension 2010), 1 Mar., 10°C (50°F) • Winter moth, Caterpillar emergence, 20 GDD, simple averaging (UMass Extension 2017), 1 Jan., 10°C (50°F) • Winter wheat , Vegetative and reproductive stages, Various; (adapted from Ritchie 1991), 1 Jan., 0°C (32°F)

Source/Link:	For information on the Pheno Forecast models the USA-NPN has operationalized and delivers as maps, visit www.usanpn.org/data/forecasts
Model Input(s)	See model details above.
Model Output(s)	Estimated date that a species will be in a given life cycle stage.
Calibration Details	Primarily available in the literature cited above and Crimmins et al. (2017); additional validation is conducted internally and available upon request.

Custom Software and Web Tools

In addition to the tools described below we leverage Tableau Desktop and Public for data exploration and partner dashboard, as well as four Google services: Maps, Reverse Geocoder, Time Zone Service and Elevation Service. The USA-NPN is a 50-year project, maintenance of the tools developed is planned across the tool's lifespan. Tools are upgraded or replaced as standards and best practices for web development change.

1	Web Services
Description:	A series of REST based web services providing input/output access to the underlining USA-NPN database. Useful for external collaborators to interface with USA-NPN data for custom built applications and data access.
Source/Link:	Documentation for use: https://docs.google.com/document/d/1yNjupricKOAXn6tY1sI7-EwkcfwdGUZ7lxYv7fcPjO8/edit Code (available upon request): https://www-dev.usanpn.org/svn/npn_ws/trunk/npn_portal
Restrictions:	Unrestricted
Languages:	PHP
Environment:	Linux

2	Nature's Notebook Web Interface
Description:	Web interface which allows *Nature's Notebook* participants to register sites, plants and animals to observe and submit phenology observations via on screen controls. Participation in shared sites, a simple phenology calendar visualization, and digital merit badges are also available through this interface.
Source/Link:	Accessible by creating an account, begin here: https://www.usanpn.org/nn/become-observer Code (available upon request): https://www-dev.usanpn.org/svn/mynpnapp/
Restrictions:	Unrestricted
Languages:	Java/JavaScript
Environment:	Linux

3	Nature's Notebook iPhone App
Description:	An iPhone app is optimized to allow *Nature's Notebook* participants to submit phenology observations on plants and animals.
Source/Link:	App: https://apps.apple.com/us/app/natures-notebook/id1463430668 Code: https://github.com/usa-npn/natures-notebook-mobile
Restrictions:	Unrestricted
Languages:	Objective C/Angular JS
Environment:	iOS 9+

4	Nature's Notebook Android App
Description:	Our Android app is optimized to allow *Nature's Notebook* participants to submit phenology observations on registered plants and animals.
Source/Link:	App: https://play.google.com/store/apps/details?id=org.usanpn.naturesnotebookmobile&hl=en_US Code: https://github.com/usa-npn/natures-notebook-mobile
Restrictions:	Unrestricted
Languages:	Java/Angular
Environment:	Android Platform 4.2+

5	Visualization Tool
Description:	A web-based visualization tool supports exploration of *in situ* phenology data via several interfaces: maps, calendars, scatter plots and activity curves (annual patterns in the timing and magnitude of plant and animal activity to show overlap in activity between species).
Source/Link:	Tool: https://www.usanpn.org/data/visualizations Code: https://github.com/usa-npn/npn-viz-tool
Restrictions:	Unrestricted
Languages:	HTML5/Javascript
Environment:	Linux/Apache

6	US Fish and Wildlife Service Dashboards
Description:	Customizable visualizations of observed and modeled data that enable US Fish and Wildlife Service Refuges to explore the data they have contributed and inform management and visitor services.
Source/Link:	Example dashboard for Valle de Oro National Wildlife Refuge: https://fws.usanpn.org/valle-de-oro

6	US Fish and Wildlife Service Dashboards
	Code: https://github.com/usa-npn/fws-drupal
Restrictions:	Unrestricted
Languages:	HTML5/Javascript
Environment:	Linux/Apache

7	Phenology Observation Portal
Description:	A web interface which supports the download of customized observational and summarized phenology data, along with Daymet temperature, precipitation and daylength data for the location at which the observations were made. Users can customize the species, locations and phenophases they need, select additional information (e.g., details about sites, quality control flags), and access metadata.
Source/Link:	Tool: https://www.usanpn.org/results/data Code: https://github.com/usa-npn/phenology-observation-portal
Restrictions:	Unrestricted
Languages:	PHP
Environment:	Linux/Node

8	Bulk Uploader Tool
Description:	This tool allows users who have set up sites and species in *Nature's Notebook* to download a datasheet in Excel format. They may then upload it with their observations. It was developed to support groups with limited internet connection and higher numbers of plants and animals.
Source/Link:	Code (available upon request): https://www-dev.usanpn.org/svn/bulk/trunk
Restrictions:	Unrestricted.
Languages:	Java/Javascript
Environment:	Linux/Tomcat/Apache

9	Geoserver Request Builder
Description:	This tool enables access and download of gridded data products curated by the USA-NPN as various raster file formats or images.
Source/Link:	Tool: https://data.usanpn.org/geoserver-request-builder Code: https://github.com/usa-npn/geoserver-request-builder
Restrictions:	Unrestricted
Languages:	Javascript/angular2
Environment:	Linux/Node

10	R Library
Description:	This library is a wrapper for USA-NPN data services, allowing easy access for R users, to USA-NPN observational and gridded data products, along with additional value-added functionality such as the ability to intersect point and gridded data.
Source/Link:	Tool: https://cran.r-project.org/web/packages/rnpn/index.html Code: https://github.com/usa-npn/rnpn
Restrictions:	Unrestricted
Languages:	R
Environment:	Windows, Linux and Mac

11	Geo Services
Description:	Services extending USA-NPN geoserver functionality in various ways such as performing raster algebra, timeseries calculations at a given lat/long, clipping maps, and computing aggregate statistics over an area.
Source/Link:	Tool: data.usanpn.org/web-services/geo.html Code: https://github.com/usa-npn/npn-geo-services
Restrictions:	Unrestricted
Languages:	nodejs/python
Environment:	Linux/Node

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