CDI SSF Category: Data and Information Assets

Development of Innovative Methods for Projecting Growing Season Under Changing Climate

Applicants/Principal Investigator(s)

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Abstract:

Climate has a direct effect on the growing season of vegetation, which impacts hydrologic response. This proposal integrates remote sensing to develop a national comparison with other growing season estimation methods used in hydrologic modeling, and evaluates the impact of these different estimates on a hydrologic simulation for the Upper Missouri River basin. This builds on previous research by expanding the number of growing season estimation methods compared, by simulating impacts over a much larger region, and by using the knowledge gained from remote sensing to improve the empirical methods. This could help improve projections of future growing seasons—which is key to better understand the future of hydrology under changing climate conditions. This project proposes to analyze and publish the source data, comparisons, and conclusions using previously established open standards-based implementations. The collaboration between the remote sensing and hydrologic modeling communities realized with this project will help to invigorate CDI Data Themes Working Group.

Total funding amount requested: $65,000

Total in-kind funding: $76,459.99

Datasets:

USGS Remote Sensing Phenology Dataset, AVHRR, national, 1989 - 2011, annual, 1000 m

Geospatial Fabric feature dataset for nat’l hydrologic modeling, contiguous US, from NHD/NHDPlus

USGS version STATSGO soils dataset, contiguous US, 30m cell size

USGS NLCD 2001 dataset, contiguous US, 30m cell size

Daymet station-based historical climate data, summarized to raster, national, 1988-2011, daily, 1km cell size

Geographic/geologic/ecosystem/habitat/taxonomic/other context:

US national, phenological-climatic-hydrological relations, hydrologic simulation

Type of Products Generated:

NSDI/GDP hosted GIS data layers, digital tabular data of historical growing season characteristics per HRU, journal article, USGS Scientific Investigations Report
Summary

Introduction and background: Growing season, in addition to being an important phenological characteristic for understanding vegetation dynamics and ecology, has an important role in controlling the hydrologic response of a watershed. A project is proposed to characterize differences between three methods of estimating growing season, including one derived from remotely-sensed data, across the United States. Historical hydrology for a large region (the Upper Missouri River basin) will be simulated using each of the estimates to demonstrate the sensitivity of streamflow response to these differences. Relations between the remotely-sensed estimates and the other two methods, which are based on temperature, will be established to improve these other methods. This is important because this means that GCM forecasts of temperature can then be used to more accurately project growing season into the future and therefore improve the science of hydrologic simulation. This project builds on previous research (Christiansen, Markstrom, and Hay, 2011), which compared two of the three methods for 14 basins across of the country and found substantive differences in growing season estimates. These authors also demonstrated that hydrologic response in a single, local-scale basin was in fact sensitive to changes in growing season estimations.

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Project Title: Development of Innovative Methods for Projecting Growing Season Under Changing Climate

Names, affiliations of all Project Leads/Principal Investigators: Roland Viger, USGS National Research Program, MS 412 Box 25046 DFC, Denver, CO 80225 Ph (303)541-3075 Email rviger@usgs.gov

Collaborating organizations with at least one point of contact, affiliation:

Water, Climate and Land Use/EROS Data Center Mission Areas, USDA, US Army Corps of Engineers

Names, affiliations of other personnel:

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Steve Markstrom, USGS National Research Program, MS 412 Box 25046 DFC, Denver, CO 80225 Ph (303)236-3330 Email markstro@usgs.gov

R. Steve Regan, USGS National Research Program, MS 412 Box 25046 DFC, Denver, CO 80225 Ph (303)236-5008 Email rsregan@usgs.gov

Adel Haj, USGS SD WSC1608 Mountain View Road, Rapid City, SD 57702 Ph (605)394-3262 Email ahaj@usgs.gov

Dave Blodgett/Nate Booth/Tom Kunicki/Ivan Suftin/Jordan Walker, USGS WI WSC/CIDA, 8505 Research Way, Middleton, WI 53562 Ph: (608)821-3899 Email dblodgett@usgs.gov

Project context and importance/value: This project is national in scope and works to use data integration to improve the scientific understanding of the connections between climate/climate change,
the growing season of vegetation, and the impacts of these changes on hydrology. It is important because it will establish a workflow for using widely available, remotely-sense data in hydrologic simulation models of all scales for historical periods and has the possibility of improving how the hydrologic model algorithms derive growing season information when using GCM forecasts of climate, which do not produce growing season estimates. The project will publish three important fundamental national data sets: 1) a raster time series of growing season based on AVHRR data, 2) a spatial discretization of CONUS based on the NHDPlus feature set used for national hydrologic model application, referred to as the Geospatial Fabric (GF; Viger and others, UGSS SIR in preparation), and 3) The results of the comparison of the three methods of estimating growing season, which will be distributed as attribute tables attached to the GF feature set.

In addition, this project will ensure that these data sets are made available to the public, and demonstrate their utility through the improvement of the state of the art of hydrological modeling. Beyond the Water (please see letter of support from Jerad Bales in Appendices) and Climate and Land Use Change Mission Areas, these data would be an important component of the National Phenology Network (please see letter of support from Jake Weltzin in Appendices).

**Scope**

This project builds on the principles of the Community of Data Integration because serving as a showcase for improving the collaboration of researchers and integration of their knowledge across traditional science discipline boundaries; it also provides important feedback that is intended to improve both involved disciplines. The collaboration is designed to generate more participation in the CDI Data Themes Working Group which, although established for over a year, has not been very active. The project will communicate the products and findings to the relevant communities in a number of explicit ways, ranging from a USGS report and a journal publication to the creation and sharing of several digital datasets using existing open standards-based applications (like NSDI, ScienceBase, and the GeoData Portal) so that the resultant science can be readily investigated, adopted, and improved upon in subsequent research. The scope of work has been carefully bounded to use pre-existing data, standards, and software in order to enable the project researchers to rapidly test impacts, improve science, and deliver data products within the constraints of the CDI calendar. The growing season data already exists, the PRMS modeling application for the Upper Missouri River is nearing completion under the auspices of other funding, and the GeoData Portal is already well established. This helps the investigators focus on scientific workflow and content in a timely manner.

**Description:** The raster time series of AVHRR-based growing season data will be compared with two other, more empirical methods of growing season estimation. These data will be digested for use in the PRMS hydrologic simulation model by using the Hydrologic Response Units (HRUs) defined by the Geospatial Fabric feature dataset (GF; Viger and others, UGSS SIR in preparation). The GF is a national set of features derived from the NHDPlus dataset specifically for hydrological modeling. The GF features are all spatially indexed to the Nation’s river networks and are an important framework for creating and sharing descriptions of the landscape for domains that use rivers as a spatial or thematic worldview. The PRMS model will be run for each of the three sets of growing seasons and results compared. The
researchers will then attempt to improve the empirical growing season estimation methods based on the AVHRR-derived information in order to better simulate future conditions (which are usually driven by daily temperature forecasts of GCMs).

Steps: 1) Make the growing season available via GDP, 2) Generate tables of per-HRU estimates of growing season using the GF, 3) Statistically compare the distributions and spatial/temporal variability of the per-HRU information, 4) generate 3 sets of PRMS input files, each based on a different growing season estimation, and run hydrologic simulations, 5) Compare the simulated streamflows, 6) Look for relations between the different estimates to improve the empirical methods.

Goals: 1) publish the remotely-sensed growing season data publicly using open-standards technology and development appropriate metadata for the earth science communities. 2) Understand spatial and temporal differences between three different growing season estimates to support better decision-making about the selection of these data for general scientific needs. 3) Create a scientific workflow for evaluating other growing season estimates (such as MODIS-derived phenometrics or content from the National Phenology Network (NPN)). 4) Quantify hydrologic sensitivity to growing season over a large US region. 5) Relate knowledge from remotely sensing to more empirical methods that can be used in a forecast/projection mode.

Milestones: 1) Publish AVHRR growing season data formally, list with GDP, NSDI, NPN. 2) Publish these and other growing season estimates by GF HRU. 3) Analyze and write up description of differences, 4) drive PRMS for Upper Missouri River basin with each of 3 estimates of growing season, 5) Analyze and write up description of differences

Partners/participants: (see collaborator list, above)

Products: 1) USGS-published digital data set of AVHRR-derived growing season. 2) USGS published set of digital tables of per-HRU growing season parameters that are readily usable with the GF. Both of these will be available via GDP, NSDI, and/or ScienceBase. 3) A USGS report on this project. 4) A journal publications on aspects of this project.

Outcomes: 1) availability for an important fundamental growing season dataset, 2) creation and availability of per-HRU growing season data that is readily usable in hydrologic modeling, 3) better understanding of differences in growing season estimation methodology, 4) better understanding of hydrologic impact of growing season, 5) better methods of estimating growing season in future conditions despite the lack of observations, 6) improved collaboration and growth of the CDI Data Themes Working Group.

**Technical Approach**

The steps are as defined in the “Steps” portion of the “Scope” section, above. This requires conversion of the AVHRR data from the ENVI files into NetCDF and the creation of a THREDDS XML catalog entry for the data. Generation of per-HRU estimates of the AVHRR growing season will be carried out by uploading the GF HRUs in a shapefile format to the GDP interface and applying it to the newly-served
AVHRR data to produce a per-HRU time series (annual time step) of growing season start and end. The two other empirical algorithms, from the USDA and the US Army Corps of Engineers, have already been implemented in Fortran by project members. These both need per-HRU estimates of daily temperature as input; these inputs will be derived using the GDP, the GF HRUs, and the DAYMET dataset (which is already being served as part of the GDP data holdings). The three sets of annual growing season will be analyzed using both ArcGIS and the R statistical package. These tabular data will be a USGS digital dataset and will be available via NSDI and ScienceBase as attribute tables that can be attached to the GF. Each of the growing season data sets will be appended to PRMS watershed modeling inputs from a pre-existing application to the Upper Missouri River by one of the project team and used by that member to re-run the simulation. The results of the three simulations will then be analyzed using a suite of tools already developed by the MoWS members of the project team. The R statistics package will be used to quantify relations between the AVHRR and empirical data, hopefully resulting in improvements to the empirical methods.

**Expertise**

Roland Viger, Steve Markstrom, and Steve Regan are all part of the Modeling of Watershed Systems (MoWS) team that produces the PRMS model and the Geospatial Fabric. Lauren Hay is the MoWS project chief. Adel Haj, a current PRMS user/collaborator, is scheduled to complete a calibration of the Upper Missouri River PRMS simulation by the end of 2012. Jesslyn Brown of the EROS Data Center is the creator of the AVHRR (and other) growing season data sets. Dave Blodgett and Nate Booth are managers/coordinators and Tom Kunicki/Ivan Suftin/Jordan Walker are programmers with CIDA and have all collaborated with MoWS on the creation of the GeoData Portal (GDP).

**Commitment to Effort**

The products of this project proposal would be of lasting value to several USGS Mission Areas (please see letters of support in Appendices). The digital data, both GIS and tabular, will be published using NSDI and/or GDP with a full metadata record as a result of the funding of this project. GDP provides OGC Catalog Services for the Web (CSW), which will greatly aid in the discoverability of these data by researchers, modelers, and other users well beyond the project team.

There are number of data assets that will be available in source data or produced that are not identified as deliverable products due to project time constraints. Despite this, there is strong interest from both the MoWS and EDC team members to continue to work with these data after the project closes. The phenology data includes an amplitude description of the increasing/decreasing signal of vegetation activity that has not been leveraged in the current proposal. The MoWS team plans to build research around this content, building upon the current project if CDI funding is secured. Jesslyn Brown has an additional growing season product from MODIS that the project team would like to evaluate in subsequent research. The PI has also spoken with Jake Weltzin about looking at a greater range of phenometric data for similar types of study. Ultimately, this research could lead to an evolution in the concepts and implementation of the PRMS hydrologic simulation model. Funding of the current
proposal would introduce several of the project members to CDI and would like encourage coordinate of this type of research through the CDI Data Themes Working Group.

In addition, the inputs and output files related the PRMS model can be made available/managed/archived using the GF, which would index hydrologic modeling information to the geospatial features used in the model application to facilitate preserving and discovering these kinds of data in a way that is much more “stream-centric” than current data life-cycle management approaches.

### Budget

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### Timeline

Over the course of the project, there will be weekly project coordination meetings and there will be monthly reports to CDI during their regular conference call. These are not explicitly listed here unless they demonstrate how we expect to address milestones.

March 31, 2013 Funding awarded from CDI
First Month: Project coordination meeting to plan scientific workflow: form data sources to processing to simulation models to analysis of results.

Second Month: Source data transformed into NetCDF-CF and will have been made available to the project via THREDDS servers within the GeoData Portal system. Research and development into resampling the raster data content to express the information according to the features of the Geospatial Fabric (GF) will have begun. Creation of metadata for publication of transformed source data sets begun.

CDI monthly meeting report (if not replaced by annual meeting). The project will have begun comparing GF-generated time-series of EDC-created data with values simulated by the methods used in the PRMS simulation model. Content for a presentation of preliminary results of comparison, as well as future plans, will be developed in anticipation for the TNM/CDI Annual meeting

TNM/CDI Annual Meeting: Presentation reviewing data sources and plans (see May 13, 2013).

Third Month: Initial PRMS simulations of hydrology based on growing season will have been carried out using both PRMS- and EDC-created values. Content for a poster at the Data Blast will be planned at this meeting. Initial content for journal manuscript drafted. Source data sets and metadata will be out for peer review. Internal project review of SIR begins.

Fourth Month: CDI Expose/Data Blast. Presentation of preliminary results of impacts of different growing season.

Review of progress of journal manuscript. Identification of potential reviewers. Responses to metadata reviews completed (hope reviewers are quick!) and process of including a copy of metadata record on an NSDI node begun.

Fifth Month: Metadata on source data should be published on NSDI and within the CSW associated with GDP. Final review discussion for journal manuscript and SIR drafts before sending out for peer review. August 14, 2013 2013: CDI monthly meeting report. August 10, 2013: Manuscript submitted to journal/USGS peer review. Fact sheet submitted for peer review.

Sixth Month: Final deliverables. All data products will be available to the public via GDP and NSDI with complete/compliant metadata. Fact sheet describing the project and the alternative growing seasons will be with EPN for layout. The principal investigator will be waiting for journal review comments.

Progress reports to CDI/monthly meeting report. IPDS/EPN documentation of final review/publication status for fact sheet. If available, journal review status reported.
1 November 2012

Roland Viger
USGS National Research Program,
MS 412 Box 25046 DFC,
Denver, CO 80225

Dear Roland:

The purpose of this letter is to support your proposal titled “Development of Innovative Methods for Projecting Growing Season Under Changing Climate” that you are submitting to the CDI FY13 call (now due 9 November 2012).

As you know, the USA National Phenology Network (USA-NPN; www.usanpn.org) is a relatively new and exciting partnership between federal agencies, the academic community, resource managers, decision-makers and the public to monitor and understand the influence of phenology on the nation’s resources, particularly within the context of variable and changing climates. The goal of the USA-NPN is to establish a continental-scale science and monitoring program focused on phenology – the periodicity of plant and animal life cycles driven by seasonal variations in climate – across a variety of spatial and
temporal scales, and to provide information for climate-informed decision-making in support of human adaptation to changing environmental conditions.

As such, I offer my strongest endorsement for your proposal. For the last several years the Network has been advocating for continental scale satellite phenology products and in particular long-term and high spatial resolution phenology indicator products. These are needed to develop fundamental phenology/climate/people research questions and to help scale organismal (in-situ ground-based) phenology measurements and observations to coarse-resolution satellite data. CDI funding for the proposed project would ensure that an important fundamental data set on the growing season is published in a form that would be widely accessible.

This project is also important because it defines quantitative approaches for comparing different types of phenological information from a hydrologic perspective. Both of these contributions would be valuable to the member of the USA-NPN, as well as to the broader ecological research community. Perhaps more importantly, under the auspices of CDI, this project would forge a positive collaboration between the ecological and hydrological communities that could also form the basis for ongoing collaboration to improve the integration of ecological and hydrological sciences within and across USGS.

As we discussed, over the last 5 years, we have been developing a national observing system and national database for both plant and animal phenology, with an eye to the land-surface phenology community. In short, our ground-based (in-situ) protocols for plants were a priori designed to complement remote sensing of phenology, because they capture not only events (e.g., budbreak) but also leaf and canopy development during the entire growing season (including quantitative estimates of leaf coloration and leaf abscission). We are now producing national datasets (e.g., deciduous tree leafing) that could be regionally subset and used for interpretation (though maybe not yet validation) of remote-sensing data, or that could be used to parameterize or validate ecohydrological models such as the one you propose. This indeed meets one of the original goals behind the establishment of the USA-NPN, i.e., to develop a new national dataset of integrated phenological observations across space and time for a variety of uses, including hydrological modeling.

We would be happy to share this dataset with you in support of your project; documentation for our web-services, data-use and data-attribution policies, metadata and a summary description of the dataset through 2011 are available from our website. We would also be happy to host links to the AVHRR dataset for our many users, especially as we start to expand into land-surface phenology and integration of our dataset with other national datasets.

In sum, your project would provide significant support to the concept and activities of the USA National Phenology Network, but also will provide a strong foundation for the development of other national phenological indicators, applications and science investigations.

Best wishes on your proposal.
Jake F. Weltzin

Ecologist, US Geological Survey

Executive Director, USA National Phenology Network

jweltzin@usgs.gov
To Community for Data Integration:

I am writing in support of the proposal Development of Innovative Methods for Projecting Growing Season Under Changing Climate (Roland Viger, PI).

Indices of changes in phenology are growing in importance as a measure of the effects of climate change, but accurate representation of phenological changes remains challenging (e.g., Cook et al., 2012). Growing season phenology has major implications for water resources. A longer growing season under a warming climate will result in greater consumptive use of water, leaving less water available for discharge to streams during low flow periods and thereby having a series of cascading effects on humans and ecosystems.

The proposed work by Viger and his many collaborators offers the potential for better understanding and identifying appropriate measures of growing season phenology in relation to water-resources response. An important outcome of this work will be a nationally consistent set of growing-season data for the entire U.S. This data set will be of great interest to the water-resources and global change communities, and likely will have other important uses. The data set also will be annually updateable with the availability of new sets of AVHRR data.

Viger has assembled an impressive set of scientists for this work. In particular, this project will develop stronger linkages between the remote sensing community and hydrology, linkages that are sorely needed as we progress to more complex hydrologic analyses and forecasts. Viger also has leveraged significant funding for this project, matching proposed CDI funding almost 1:1. Finally, the groups (the Modeling of Watershed Systems group and the Center for Integrated Data Analytics) potentially involved in this project have a strong track record of generating useful products that exceed expectations.

I strongly encourage you to carefully consider this proposal for funding.

Sincerely,

[Signature]

Jerad Bales
Chief of Research and Science for Water