Supporting Collaborative Model and Data Service **Development and Deployment** with **DevOps**

Olaf David¹, Mazdak Arabi¹, Jack Carlson¹, Kyle Traff¹, Wes Lloyd², Ken Rojas³

H41B-1327

¹ Colorado State University, Fort Collins

² University of Washington, Tacoma

³ USDA Natural Resources Conservation Service, Fort Collins

Abstract

Efficient deployment of modeling technology and data management using a Service-oriented Architectures SoA in a scientific research environment requires the efficient management of rapid

development/deployment cycles. Changes of modeling solutions are frequent and must be quickly made available to the collaborating community.

DevOps provides best practices, tools, and organizational structures to optimize the transition from model service development to deployment by minimizing the operational burden and turnaround time for (model) developers. We have developed and implemented a methodology by integrating a suite of tools for application lifecycle management, version control, continuous integration, container management, and container scaling to enable model and data service developers in various institutions to collaboratively build, run, deploy, test, and scale services within minutes. Our methodology automates most of the workflow for service roll out and deployment.

Clouds provide an excellent platform for service deployment, however, they do not provide usually workflow and comprehensive resource management. Scientific computing in cloud environments typically suffer from heavy virtualization overhead due to OS replication on the VM. Leveraging experience managing scientific service deployments on Eucalyptus and Amazon we have developed a continuous workflow for service deployment and delivery using Kubernetes/Docker, Jenkins CI and Mercurial/Git.

We use the implemented workflow to develop, deploy and test micro services developed using the Cloud Services Integration Platform (CSIP). CSIP is a RESTful/JSON based service infrastructure based on the Object Modeling System, which was developed at Colorado State University providing for collaborative integration of environmental models into scalable model and data services as a micro-services platform.

CSIP/DevOps make model service improvements available in a short amount of time while engaging a wider community of model service users in testing and model evaluation while taking into account deployment scalability, redundancy and reliability, access security, and development efficiency.

Contact

Olaf David odavid@colostate.edu http://www.engr.colostate.edu/~odavid





Introduction

The Cloud Services Integration Platform (CSIP) developed over the last 5 years at Colorado State University provides for collaborative integration of environmental models into scalable model and data services as 'micro-services' platform with API and deployment infrastructure. CSIP, initially developed to support USDA natural resource applications, has proven to be suitable for a wide range of scientific applications spanning environmental modeling. To date, more than 160 model and data services are available for applications in hydrology (PRMS, Hydrotools, CFA, ESP), water and wind erosion prediction (WEPP, WEPS, RUSLE2), soil quality trends (SCI, STIR), water quality analysis (SWAT-CP, WQM, CFA, AgES-W), stream channel degradation assessment (SWAT-DEG), hydraulics (cross-section), and grazing management (GRAS). In addition, supporting data services include soil (SSURGO), ecological site (ESIS), climate (CLIGEN, WINDGEN), land management and crop rotations (LMOD), and pesticides (WQM), developed using this workflow automation and decentralized governance.

Adopting DevOps practices for model service development and deployment enables a community to engage in service-oriented modeling and data management. While extending its scope and visibility it became apparent community integration and adequate work flow support through the full model development and application cycle drove successful outcomes. DevOps provide best practices, tools, and organizational structures to optimize the transition from model service development to deployment by minimizing the (i) operational burden and (ii) turnaround time for modelers. We have developed and implemented a methodology to fully automate a suite of applications for application lifecycle management, version control, continuous integration, container management, and container scaling to enable model and data service developers in various institutions to collaboratively build, run, deploy, test, and scale services within minutes.

s code Beamer	Application Lifecycle Management
gin Projects 🔻 Wiki 🔻 Documents 🔻 Trac	kers V Reports V SCM Repositories V
CSIP	
Wiki #6847 v259 0	
Tags: Cloud MaaS Modeling REST Services	SQA
Cloud Services Integrati	on Platform (CSIP)
	nentation to offer a Model-as-a-Service framework, Application Programming Inte Is JAX-RS and OMS3 (), currently offering 200+ different model and data service
	IS JAX-RS and OMS3 , currently offering 200+ different model and data service
This project provides all information to explore existing, dev	
categorized by domain groups by client application as listed	
categorized by domain groups by client application as listed Development.	elop new, and access provided CSIP services. If you want to browse the full list, below. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category.
categorized by domain groups by client application as listed	
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual 3	below. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category
categorized by domain groups by client application as listed Development. Service Development	below. If you want to develop CSIP services and/or want to use them in your app
categonized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual D CSIP Platform Repository Frequently Asked Questions	below: If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual 2 CSIP Platform Repository 2	below. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual CSIP 2.0 Manual CSIP Platform Repository Frequently Asked Questions Continuous Integration with Jenkins	below. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management Comprehensive Flow Analysis (CFA) (12 services) Baseflow, Flood, Drought, Flow Duration, Load Duration, State discharge,
categonized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual D CSIP Platform Repository Frequently Asked Questions	below. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management Comprehensive Flow Analysis (CFA) (12 services)
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual CSIP 2.0 Manual CSIP Platform Repository Frequently Asked Questions Continuous Integration with Jenkins	beiow. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management Comprehensive Flow Analysis (CFA) (12 services) Baseflow, Flood, Drought, Flow Duration, Load Duration, State discharge, Watershed Rapid Assessment Program (WRAP) (11 services)
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual (2) CSIP Platform Repository (2) Frequently Asked Questions Continuous Integration with Jenkins Tutorials	below. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management Comprehensive Flow Analysis (CFA) (12 services) Baseflow, Flood, Drought, Flow Duration, Load Duration, State discharge, Watershed Rapid Assessment Program (WRAP) (14 services) Impaired streams, Wetlands, Water Treatment plants, Impaired Water box
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual CSIP Platform Repository Frequently Asked Questions Continuous Integration with Jenkins Tutorials Developing Services (Docker)	beiow. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management Comprehensive Flow Analysis (CFA) (12 services) Baseflow, Flood, Drought, Flow Duration, Load Duration, State discharge, Watershed Rapid Assessment Program (WRAP) (11 services) Impaired streams, Wetlands, Water Treatment plants, Impaired Water bo Groundwater Data Analysis (1 service) Groundwater data analysis (ncluding a statistical summary of time seriest Hydrotosis (6 services)
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual CSIP Platform Repository Frequently Asked Questions Continuous Integration with Jenkins Tutorials Developing Services (Docker)	beiow. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management Comprehensive Flow Analysis (CFA) (12 services) Baseflow, Flood, Drought, Flow Duration, Load Duration, State discharge, Watershed Rapid Assessment Program (WRAP) (11 services) Impaired streams, Wetlands, Water Treatment plants, Impaired Water bo Groundwater Data Analysis (1 service) Groundwater data analysis (ncluding a statistical summary of time seriest Hydrotosis (6 services)
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual CSIP 2.0 Manual CSIP 14form Repository Frequently Asked Questions Continuous Integration with Jenkins Tutorials Developing Services (Docker) Invoking Services (Docker) Deployment Overview	below. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management Comprehensive Flow Analysis (CFA) (12 services) Baseflow, Flood, Drought, Flow Duration, Load Duration, State discharge, Watershed Rapid Assessment Program (WRAP) (11 services) Impaired streams, Wetlands, Water Treatment plants, Impaired streams, Wetlands, Water Streams, Vetlands, Under Do Groundwater Data Analysis (11 service) Groundwater data analysis, including a statistical summary of time seriest Hydrotolosi (16 services) TR-20 bydrotology and Sacociated converters for HEC-RAS, regional clima Integrated Urban Water Model (IUWM) (21 (1 service)
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual CSIP 2.0 Manual CSIP Piatform Repository Frequently Asked Questions Continuous Integration with Jenkins Tutorials Developing Services (Docker)	beiow. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management Comprehensive Flow Analysis (CFA) (2 services) Baseflow, Flood, Drought, Flow Duration, Load Duration, State discharge, Watershed Rapid Assessment Program (WRAP) (1 services) Impaired streams, Wetlands, Water Treatment plants, Impaired Water bo Groundwater Data Analysis (1 service) Groundwater Data Analysis (1 service) TR-20 hydrology and associated converters for HEC-RAS, regional climat Integrated Urban Water Model (UVM) (1 service) Forecast urban water Meden during a statistical savings from conserv
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual 3 CSIP	below. If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management Comprehensive Flow Analysis (CFA) (12 services) Baseflow, Flood, Drought, Flow Duration, Load Duration, State discharge, Watershed Rapid Assessment Program (WRAP) (11 services) Groundwater Data Analysis, Including a statistical summary of time series Hydrotols (15 evrice) TR-20 hydrology and associated converters for HEC-RAS, regional cilmal Integrated Urban Water Model (UMM) (15 ervice) Foreceast urban water Model (UMM) (21 service) Foreceast urban water meam and project potential savings from conserv SWAT-DEG (1 service)
categorized by domain groups by client application as listed Development. Service Development CSIP 2.0 Manual 3 CSIP 2.0 Manual 3 CSIP 2.0 Manual 3 CSIP 7 CSIP 7	beiow: If you want to develop CSIP services and/or want to use them in your app Deployed Services by Category Hydrology and Water Resources Management Comprehensive Flow Analysis (CFA) (2 services) Baseflow, Flood, Drought, Flow Duration, Load Duration, State discharge, Watershed Rapid Assessment Program (WRAP) (1 services) Impaired streams, Wetlands, Water Treatment plants, Impaired Water bo Groundwater Data Analysis (1 service) Groundwater Data Analysis (1 service) TR-20 hydrology and associated converters for HEC-RAS, regional clima Integrated Urban Water Model (UVMM) (1 service) Forecast urban water Medma and project potential savings from conserv

Jenkins setup for service build, deployment and testing. It is enabled to allow for remotely triggering builds and deployments

Objectives

Our operational workflow enables decentralized builds and deployment of services: • Support developers to easily deploy a new service to a platform for internal testing and results evaluation.

- Enable developers to remotely trigger service builds, deployments, and tests using a common web user interface.
- Manage service configuration changes without interrupting service availability while addressing failure through enabling roll backs to previous working versions

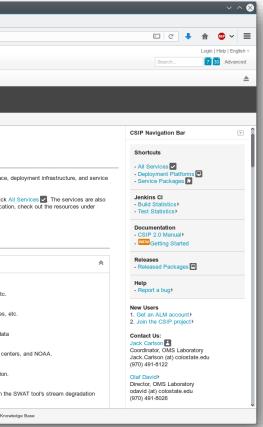
Methods and Approaches

We integrated the following tools to implement this workflow: CSIP

- Jenkins

- Codebeamer ALM
- lifecycle.
- Mercurial
- Kubernetes

https://alm.enar.colostate.edu/cb/project/csip



The CSIP Project Application Lifecycle Management site to manage resources such as Repositories, Tracker, Service endpoint descriptions, Documentation,

			ServiceTests [Jenkins] - Mozilla Firefo	x					~
Search		(i) (ii) (iii) (ii	du/ienkins/view/ServiceTests/					e 🖡	
Jenkins						[earch		Iog
Jenkins > ServiceTests >								EN/	ABLE AUTO REFRE
_		CSIP Service Tests and Statistics							
Neople		All CoCoRaHS Deployment	ts ServiceBuilds ServiceChecks	erviceTest	ta .				
Build History		All CocoRaHS Deployment	Is ServiceBuilds ServiceChecks	erviceles	15				
Project Relationship		Test Trend Chart		* 23	Test Statistics Chart				*
🛄 Check File Fingerprint		400				failed			
Build Queue	_	350				= 43 (10%)			
	-	불 ²⁵⁰				skippe d = 0 (0%)			
No builds in the queue.		200 150				(0.%)			
Build Executor Status	_	100							
1 Idle		50					S S S S S S S S S S S S S S S S S S S	cces	
2 Idle									
3 Idle		8 8 8 8 8	88666999111						
4 Idle	Test Statistics Grid					4			
		Job 1	Success #	%	Failed #	%	Skipped #	%	Total #
			Gaccess "					10	
			90	100%	0		0	0%	
		Csip-erosion tests	90	100% 0%	0	0%	0	0% 0%	
		Comparison tests Monoperative tests	0	0%	3	100%	0	0%	1
		Colperosion tests Colperosion tests Colperando test	0 178 22 6	0% 91% 92% 100%	3 18 2 0	100% 9% 8% 0%	0 0 0	0% 0% 0%	1
		(#esip-erosion tests (#esip-erosion tests (#esip-aros tests (#esip-aros tests (#esip-rot tests (#esip-rot tests (##esip-rot tests (##esip-rot tests	0 178 22 6 0	0% 91% 92% 100% 0%	3 18 2 0 4	100% 9% 8% 0% 100%	0 0 0 0 0	0% 0% 0% 0%	1
		() csip-erosion tests () csip-erosion tests () csip-example tests () csip-gras tests () csip-lined tests () csip-solit-tests () csip-solit-tests () csip-solit-tests () csip-solit-tests	0 178 22 6 0 84	0% 91% 92% 100% 0% 84%	3 18 2 0 4 16	100% 9% 8% 0% 100% 16%	0 0 0 0 0	0% 0% 0% 0% 0%	1
		(#esip-erosion tests (#esip-erosion tests (#esip-aros tests (#esip-aros tests (#esip-rot tests (#esip-rot tests (##esip-rot tests (##esip-rot tests	0 178 22 6 0	0% 91% 92% 100% 0%	3 18 2 0 4	100% 9% 8% 0% 100%	0 0 0 0 0	0% 0% 0% 0%	1
		() csip-erosion tests () csip-erosion tests () csip-example tests () csip-gras tests () csip-lined tests () csip-solit-tests () csip-solit-tests () csip-solit-tests () csip-solit-tests	0 178 22 6 0 84	0% 91% 92% 100% 0% 84%	3 18 2 0 4 16	100% 9% 8% 0% 100% 16%	0 0 0 0 0	0% 0% 0% 0% 0%	11 : 11 4;
		Gigsperosion tests Gigsperosion tests Gigsperosion tests Gigsperositests Gigsperositests Gigsperositests Gigsperositests Gigsperositests Gigsperositests Total	0 178 22 6 0 84	0% 91% 92% 100% 0% 84%	3 18 2 0 4 16	100% 9% 8% 0% 100% 16%	0 0 0 0 0 0	0% 0% 0% 0% 0%	1 1 4 2
		:#esip-erosion tests @resip-erosion tests @resip-example tests @resip-gras tests @resip-rate tests @resip-solita-tests @resip-solita-tests @resip-solita-tests Total Test Job IIst	0 178 22 6 0 84 380	0% 91% 92% 100% 0% 84% 90%	3 18 2 0 4 16 43	100% 9% 8% 0% 100% 16%	0 0 0 0 0 0	0% 0% 0% 0% 0% 0%	
		(#csip-erosion tests (#csip-erosion tests (#csip-erosion tests (#csip-erositests (#csip-rate tests (#csip-ratettest (#csip-rate testests (#csip	0 178 22 6 0 84 380 Kast Success	0% 91% 92% 100% 0% 84% 90%	3 18 2 0 4 16 43	100% 9% 8% 0% 100% 16%	0 0 0 0 0 0 0	0% 0% 0% 0% 0% 0%	1 1 4 Ouration 6 sec

• Track deployments in version history to capture provenance.

• Provide multiple event based methods to trigger services deployment in response to version control actions, remote URL triggers, or direct UI triggers. • Encapsulate management of software dependencies throughout micro services deployment to ensure all components are available for proper service operation.

• The Cloud Services Integration Platform is a cross-platform Model-as-A-Service platform tailored for implementing and deploying environmental model and data services. It is a Java-based framework.

• Jenkins is a cross-platform, continuous integration and delivery application helps to automate the non-human part of the whole software development process with now common things like continuous integration, but by further empowering teams to implement the technical part of a Continuous Delivery.

• Codebeamer is an Application Lifecycle Management Platform that integrates tools for managing resources and tracking progress of the entire software

• Mercurial is a distributed source control management tool. It efficiently handles projects of any size and offers an easy and intuitive interface.

Kubernetes is an open source container cluster manager providing a platform for automating deployment, scaling, and operations of application containers across clusters of hosts. It integrates with Docker.

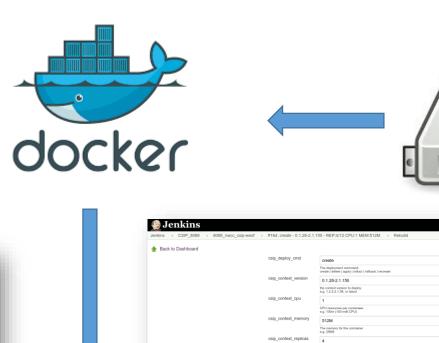




🗉 csip-	ewsf 💌 🛛 🗤	lercurial repos	itory by wlloyd						
Clone	t https://alm.	engr.colosta	ite.edu/cb/hg/csip-e ite.edu/cb/hg/csip-e				Siz		ov 30 10:43 0.8 MB pending
Forks	Changes	Files	Pull Requests	Branches & Tags	Permissions	Notifications	Statistics		
Branch/Ta	g default	<u>.</u>	SCM Repositor	у					
SCM 🗖 🗄	Repository ploy		Name	Rev.			Date	Author	Comment
 Iib Inbproject 		🗖 deploy	edbe3136d37ae	e566adb8fbef31e07	26a956b55d6	Nov 19 14:52	od	Merge	
🕸 🛄 sr 🕀 🛄 te	st		🗖 lib	0c8e85e3678b8	39fcc145c8d86bcel	b722504af8ca	Mar 17 2015 13:57	od	initial
🗄 🛄 wi	əb		D nbproject	73ef0b505b919	0c2f7f9a7ea37ae1	5233e02b032	Nov 28 09:25	od	dep:nwcc
			🗖 src	5b66d4c67b815	563df0c4484eea18	535f1aa16378	Nov 30 10:42	od	dep:nwcc
			🗖 test	78fcbcdcc28a1	1b561442e19c5430	d839123e5687	Nov 19 14:47	od	new: total time measure
			🗖 web	edbe3136d37ae	e566adb8fbef31e07	26a956b55d6	Nov 19 14:52	od	Merge
			.hgignore	322e3163f3350	aa1de074695af51a	a8e3b98c7322	Apr 02 2015 08:56	od	Ignore results
		.hgtags	69e192e9b6d50	090a43278c68220e	b60e92790460	Nov 28 18:34	od	Removed tag bbb	
			build.xml	d2523f4f60480	c451072e1ce52815	1a2a6a33e67c	Mar 02 12:37	od	cha: jdk.8 new jenkins support

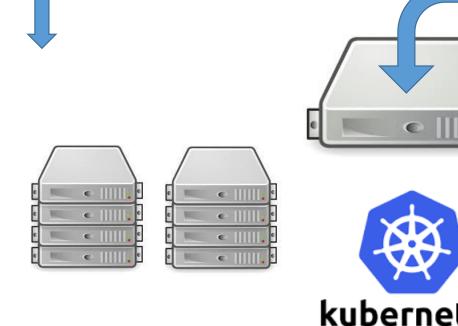
Source code repository hosted on Codebeamer ALM

https://alm.engr.colostate.edu/Jenkins/



csip_service_peers=4 csip_session_ttl=PT20S Deployment history is kept in

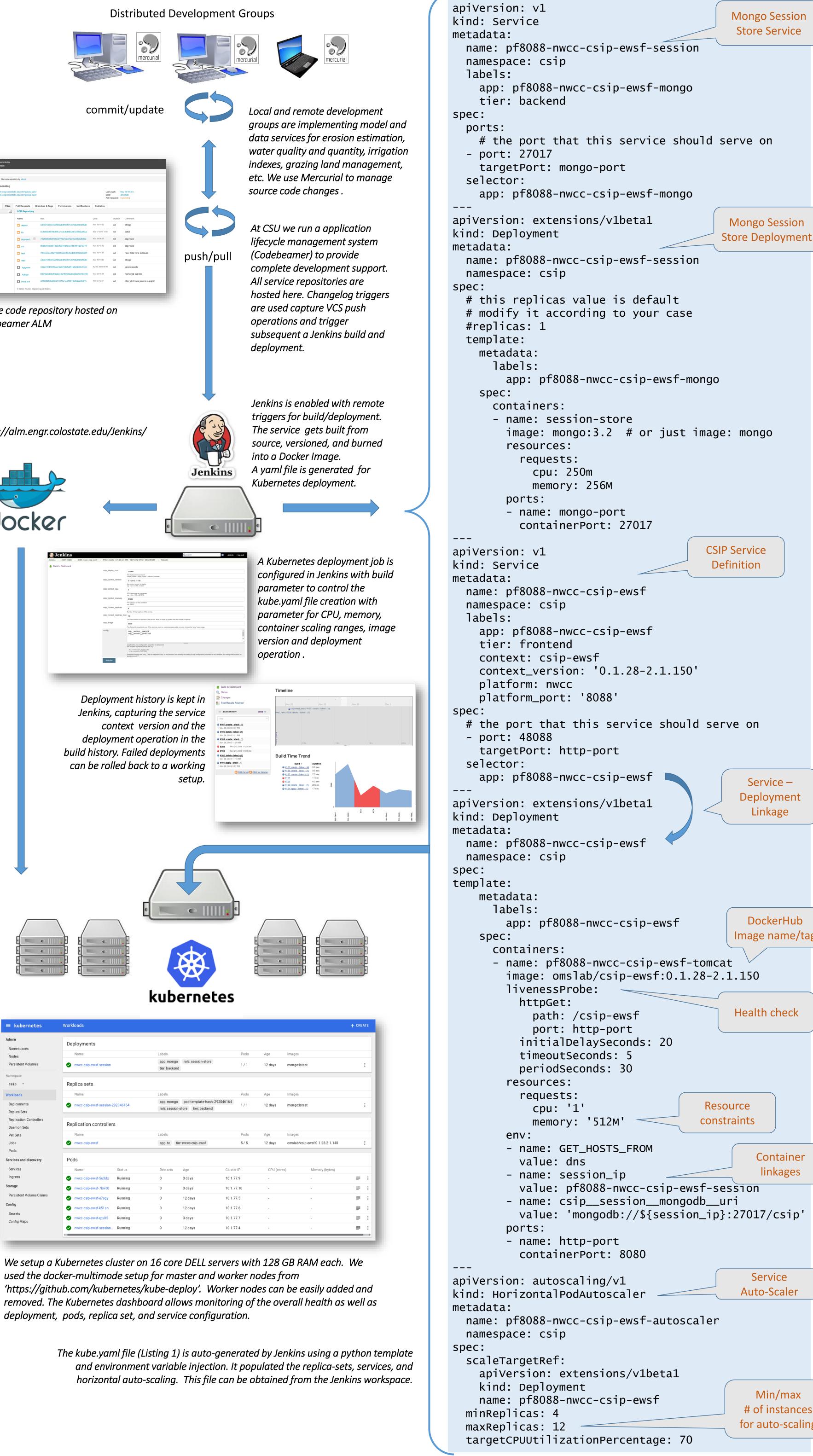
Jenkins, capturing the service context version and the deployment operation in the build history. Failed deployments can be rolled back to a working



dmin	Deployments			
Namespaces Nodes	Name	Labels		
Persistent Volumes	Nwcc-csip-ewsf-session	app: mongo tier: backen		
lamespace				
csip *	Replica sets			
Vorkloads	Name	Labels		
Deployments Replica Sets	Nwcc-csip-ewsf-session-292046164	app: mongo role: session		
Replication Controllers Daemon Sets	Replication controllers			
Pet Sets	Name	Labels		
Jobs	Nwcc-csip-ewsf	app:tc ti		
Pods				
ervices and discovery	Pods			
Services	Name Status	Restarts		
Ingress	nwcc-csip-ewsf-5u3dx Running	0		
torage	onwcc-csip-ewsf-7bwt0 Running	0		
Persistent Volume Claims	Nwcc-csip-ewsf-e7sgy Running	0		
Config	Nwcc-csip-ewsf-k51sn Running	0		
Secrets	wcc-csip-ewsf-rpy05 Running	0		
Config Maps	nwcc-csip-ewsf-session Running	0		
	C.			

used the docker-multimode setup for master and worker nodes from deployment, pods, replica set, and service configuration.

Workflow Implementation

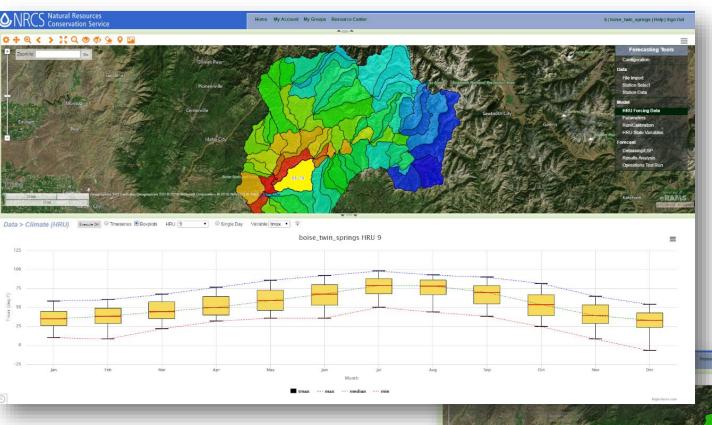


Application Example – Detrended Kriging Service

CSU is developing in cooperation with the NRCS National Water and Climate Center the next generation water supply forecasting system (eWSF). This system is being used to perform seasonal water availability forecasts to support water management decision in agriculture. This project aims to increase the functionality and efficiency of the water supply forecasting workflow deployed and operated by the NWCC. The system retrieves, processes, and de-biases climate data input for the PRMS model for twice-monthly water supply forecasts in the 600 forecast basins of the western United States. It analyzes and displays output to forecast hydrologists and provides data feeds to public facing portals and applications. It is implemented using the eRAMS geospatial platform and CSIP service infrastructure.

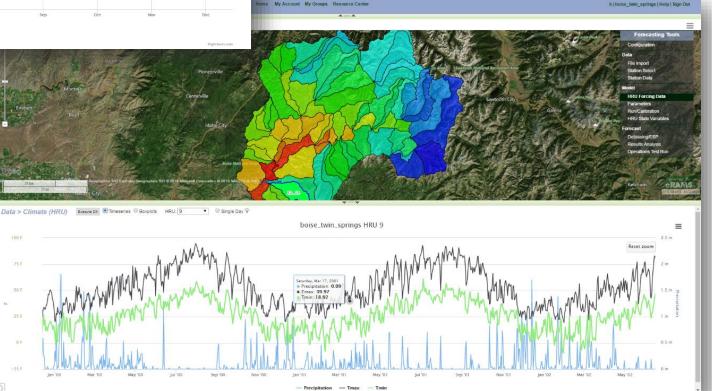
eWSF utilizes a *Detrended Kriging* service, which is based on the DK program (Garen et. al, 1994). The purpose of this program is to estimate spatial fields of precipitation, temperature, and snow water equivalent by interpolating among point measurements from standard surface stations. The program was written with daily time series data in mind, but it can also be used to interpolate data at other temporal resolutions, and it can be used for long-term averages.

The DK service uses climate station data/metadata and a DEM and HRU map as input and produces a climate data set with daily values for each HRU. The eWSF service package containing the DK service was automatically deployed on the Kubernetes container cluster using 64 cores using the yaml script shown in Listing 1.



eWSF GIS user interface to manage geospatial data such as HRU (Hydrologica *Response Unit) maps. The HRU map can be* used to visualize the result of DK for computing tmin, tmax, and precip for a given HRU over a period of time using boxplots.

The generated time series for tmin, tmax, and precip can be visualized at the HRU level. The geospatial map and the time series plots are connected to a allow an interactive exploration of DK results.



Results

- We implemented the presented workflow at CSU and using it for multiple projects. - The time from committing a source code change to have a service available in multiple container replica set is less than **10 seconds** on average
- The version control system and CI are tracking a deployment history, either triggered by VCS commit hooks or CI builds.
- Service orchestrations can be adjusted by customizing the Kubernetes template.
- Creating a topology of services and taking them down without manually managing Kubernetes 'yaml' files is efficient.
- Model service developers can individually build test and deploy at scale without central governance.

Conclusions

We have implemented more than 160 model and data services for applications in hydrology (PRMS, Hydrotools, CFA, ESP), water and wind erosion prediction (WEPP, WEPS, RUSLE2), soil quality trends (SCI, STIR), water quality analysis (SWAT-CP, WQM, CFA, AgES-W), stream degradation assessment (SWAT-DEG), hydraulics (cross-section), and grazing management (GRAS), and supporting data services (SSURGO, ESIS, CLIGEN, WINDGEN), land management and crop rotations (LMOD), and pesticides (WQM), developed using this workflow automation and decentralized governance.

Container-based deployment using Kubernetes, Mercurial, and Jenkins provides all tools to allow for a continues delivery of scientific applications. Using the implemented workflow, we were able to allow a developer driven deployment for service testing in short amount of time while ensuring scalability. In addition we can track deployment history, revisit deployment parameter by leveraging Jenkins and Kubernetes features.

The implemented development and deployment solution is actively being used in several research projects.

Resources

- CSIP project: http://alm.engr.colostate.edu/cb/project/csip

- David, O., Lloyd, W., Rojas, K., Arabi, M., Geter, F., Ascough II, J., Green, T., Leavesley, G. and J. Carlson, 2014, Model-as-a-Service (MaaS) using the Cloud Services Innovation Platform (CSIP), In: Ames, D.P., Quinn, N.W.T., Rizzoli, A.E. (Eds.), Proceedings of the 7th International Congress on Environmental Modelling and Software, June 15-19, San Diego, California, USA. ISBN: 978-88-9035-744-2

- Garen, D. C., G. L. Johnson, and C. L. Hanson (1994). Mean areal precipitation for daily hydrologic modeling in mountainous regions. Water Resources Bulletin, 30(3), 481-491. - Kubernetes project: http://kubernetes.io

- eRAMS platform: http://erams.com